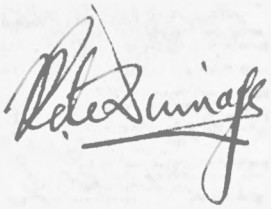
The Autocar HANDBOOK

TWENTIETH EDITION



The Autocar HANDBOOK

COMPANION VOLUMES

The Autocar GUIDE FOR THE "L" DRIVER

MOTOR DRIVING MADE EASY
By *The Autocar* Technical Staff

KNOW YOUR CAR
By *The Autocar* Technical Staff

LOOK AFTER YOUR CAR
By *The Autocar* Technical Staff

TOWN-TO-TOWN MILEAGES
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The Autocar HANDBOOK

FOR THE MOTORIST

By

The Autocar

Technical Staff

Over 280 Illustrations

Twentieth Edition

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Foreword

FOR forty years "*The Autocar*" *Handbook* has been the recognised guide for the owner-driver who desires to have a general knowledge of the basic principles governing the operation and maintenance of his car. During that period it has passed through nineteen editions, as well as a number of additional revisions, so that it has continuously reflected the most up-to-date practice.

Several new editions have been called for since 1939, mainly because of training requirements in the armed forces and also because those civilians still permitted to use cars in connection with their essential work were frequently thrown upon their own resources for repair and maintenance, and found it necessary to learn something of the principles of the mechanism which previously they had accepted as a matter of course.

The treatment adopted in explaining the mechanism is essentially not highly technical, thus rendering this book suitable for those without theoretical or engineering training ; at the same time it delves sufficiently deeply into car design and the reasons behind the variations in practice between make and make to be of service to the knowledgeable motorist who wishes to learn more of his car's construction and operation.

This, the twentieth edition, is the second to be produced since the war terminated. It has again been brought up to date so as to give a fair indication of cars as they are being made to-day, and includes notes upon changes and improvements which are beginning to find their way into new designs as the result of experience gained in the hard years of the war, when cars had to run for long periods with the minimum of service and repair.

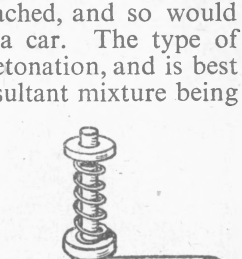
It is believed that the information contained in this book will be found valuable to those who desire to acquaint themselves with the main principles involved in the mechanism of a car in order to ensure the best road service from good treatment of the essential points.

CHAPTER 1

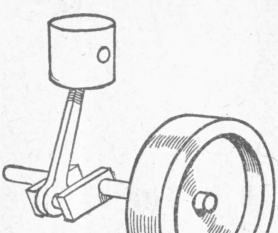
The Engine

STRIPPED of all complications, the petrol engine is a very simple thing. Briefly, you have a cylinder, and in that cylinder the piston. The piston is attached to a rod, of which the other end is on a crank, itself attached to a shaft. Now if some sort of explosion could be created above the piston in the cylinder, the piston would be driven downwards, pushing the rod and the crank and thereby turning the shaft to which the crank is attached, and so would enable you to make the engine drive a car. The type of explosion needed is not as violent as a detonation, and is best created by mixing petrol with air, the resultant mixture being best explained as a gas. The petrol-and-air gas must be fed into the cylinder, caused to explode and the residue of the explosion allowed to escape, so that a fresh charge can come in.

The entry and departure of the gas could be arranged with the aid of taps if mechanism could be obtained to operate the taps at the right moment, but the real solution of the problem is not a tap but a valve. A valve, quite simply, is a mushroom-shaped piece of steel (with a coned edge to the mushroom) arranged to make an air-tight joint with a coned ring machined in the top of the cylinder. To keep the valve upright, it is mounted in a guide. To keep it gastight it is held against its seat, as the coned ring in the cylinder is called, by one or more coil springs. One end of the spring can rest upon some fixed part of the cylinder head, the other in a metal



The valves are mushroom-shaped pieces of steel which cover the ends of the inlet and exhaust pipes, and the edges of the valves and of the pipes are bevelled so that the valves can have a good gas-tight seat. The stems of the valves slide in guides, so that the heads of the valves may come squarely on to their seats, and springs are arranged round their stems



The piston with its connecting rod is attached to a crankshaft at one end of which is the flywheel

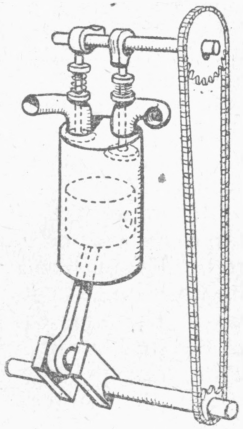
washer called a collar, threaded over the valve stem and held in position by a pin pushed through a hole in the valve stem, the pin being called a cotter-pin. A valve of this type can easily be mounted so that part of its stem and head is inside a passage which is part of the cylinder head, while the rest of the stem protrudes through the guide, so that the spring and collar are outside in the open air. A certain mechanism which will be described later is then made to push this valve off its seat against the spring just as the piston commences to slide downwards in the cylinder.

The initial movement of the piston is caused either by attaching a handle to the crankshaft or by making an electric motor do the work. As the piston moves downwards, gas is sucked into the cylinder through the open inlet valve. The piston moves until the crank has turned from the top to the bottom of a circle ; further movement of the crank must, therefore, cause the piston to slide up again, because the crank must revolve in a circle. Just as the piston commences to move upwards, the inlet valve is released and held against its seat by the coil spring. Since the gas cannot now escape from any part of the cylinder, it is compressed as the piston rises. Petrol and air compressed is a very much better explosive than petrol and air at normal pressure, hence the need for compression. When the piston has reached the top of its upward movement and just begun to go down again, an electric spark is made to explode the compressed gas in the cylinder. The consequent rapid expansion of this gas pushes the piston rapidly downwards again, thereby driving the crank and its shaft round.

The piston is provided with a number of metal packing pieces, which are springy rings of cast-iron working in grooves in the piston

That is the first moment when the engine is working under its own power. From that moment the starting handle or the electric motor is unnecessary. As soon

as the piston has reached the end of its travel under the pressure of the explosion it commences to rise again. At that exact moment another valve is pushed off its seat in the cylinder head, and allows the exhausted gas to escape through a pipe, assisted by the rapidly rising piston. The exhaust valve in its turn is closed when the piston has reached the top of its stroke, and at that point the inlet valve opens again and the whole process is repeated : inlet, compression, firing, exhaust, the piston moving downwards for the inlet and explosion, upwards for compression and exhaust.



Use is made of a rotating rod or shaft on which there are two projections or cams. This is the camshaft, and it is connected to the crankshaft by two wheels or by a chain

Manifestly, a crude crank and shaft arranged in this manner would not continue to rotate long enough to make the necessary number of turns before the next inlet stroke. Therefore a flywheel, that is, a disc of metal with a heavy rim, is attached to the shaft, and the energy put into this wheel when the explosion occurs is stored and given back in the work done, making the shaft continue to run.

Since an explosion is a thing which creates a great deal of heat, and a cylinder would rapidly become red-hot if some way could not be found of cooling it, a jacket is formed round its outside, and this jacket is filled with water.

Also it is important that the piston remains gastight, for which purpose it is provided with a ring of cast iron cut at one point so that there is a gap between the two ends. This ring is slightly larger than the diameter of the cylinder, but when held in a groove in the piston and pushed into the cylinder is able to conform to the size of the cylinder by closing up the gap between the two ends, like a snake bangle. In doing so it exerts a pressure on the surface of the cylinder and therefore acts as a gas seal. There are usually two or three of these rings with their gaps out of line on the piston.

Coming now to the detail, we have to consider first of all the means of opening the valves at the right time. Since the crank-

shaft makes two complete revolutions to complete its cycle (inlet, compression, firing and exhaust), whereas the valves are open only once for the inlet, once for the exhaust stroke, those valves have to be operated by a shaft which runs at half the speed of the crankshaft. Accordingly, there is a gear on the crankshaft which drives another gear of twice its diameter attached to a shaft for operating the valves. On this second shaft are two cams.

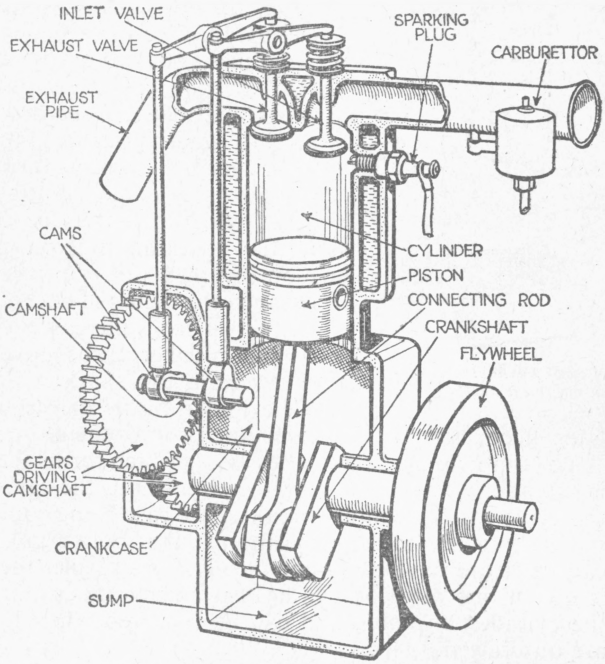
Now a cam is a mechanical device which will convert a rotary into an up-and-down or reciprocating movement, and it consists of a disc of steel, circular and running true with the camshaft for the most part, but having one thick extension. When this cam is running, if you were to put your finger on it, the finger would be raised every time this extension came round, lowered as soon as it had passed ; exactly the movement that is required.

Resting on the cam is a rod held in a guide recessed at the top to receive one end of another long thin rod called the push-rod. The push-rod is taken up to the cylinder head and there it moves one end of a rocking lever which is exactly like a see-saw. The other end of this rocking lever operates on the end of the stem of the valve. When the crankshaft is driving the camshaft, the cam pushes the push-rod upwards and the rocking lever forces the valve off its seat. When the cam has passed, the valve spring returns the valve to its seat, and incidentally pushes the rocking lever and push-rod back again. The small rod in immediate contact with the cam is called a tappet.

It is quite easy to see that by meshing the two gears, one on the crankshaft and one on the camshaft, so that the cam is in a certain position, a valve can be caused to open at any desired moment, and the cam can be shaped so that the valve closes a certain time after it is opened. That makes it easy to open the inlet valve with this mechanism exactly when it is required, and to do the same thing with the exhaust valve.

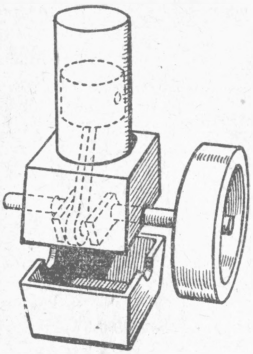
Sometimes, by the way, the valves are not in the head of the cylinder, but to one side of the head, and instead of their stems pointing upwards they point downwards. It is then possible to make the stem long enough to be operated direct by the tappet. An engine with this system is called a side-valve engine ; one with the push-rod and rocking lever an overhead valve (o.h.v.) engine.

Remains to cause the spark to occur at the right moment,



A single-cylinder engine in simple form. The inlet and exhaust valves are operated by the cams on the camshaft which is rotated at half camshaft speed by two gear wheels. The sparking plug ignites the petrol and air mixture supplied by the carburettor

which entails driving another shaft from the crankshaft at half engine speed and arranging on this shaft a miniature cam which, instead of operating a tappet and push-rod, switches current on and off to a coil by causing one end of a rocking lever to separate from a fixed stop, and thereby interrupting the current. What is known as an induction coil can be arranged so that if a small current is caused to flow in it and then suddenly switched off, a very powerful current will be generated in a separate surrounding coil of wire. If this very powerful current is carried by wires to what is known as a sparking plug, it will jump across a gap between two wires in that end of the plug which is screwed right into the cylinder



A heavy wheel, the flywheel, is mounted on the crankshaft

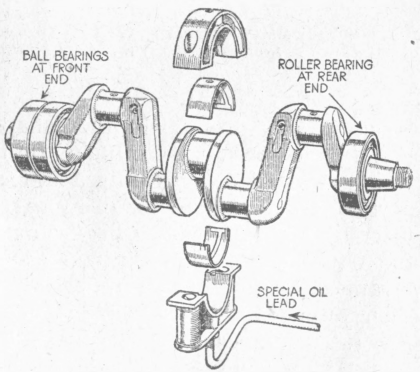
head, thereby causing a spark sufficiently effective to explode the gas.

To make the thing more definite, a shaft driving the switch gear, called a contact-breaker, also drives separately a rotating metal finger. To this finger high-tension current is fed, and the finger comes opposite a brass plate, which can thus be connected to the sparking plug at the exact moment that the spark is required between the points of that plug. Here again you see quite easily that if the contact-breaker can be moved relative to its cam, the spark will occur in the cylinder a little earlier or a little later according to the direction of movement.

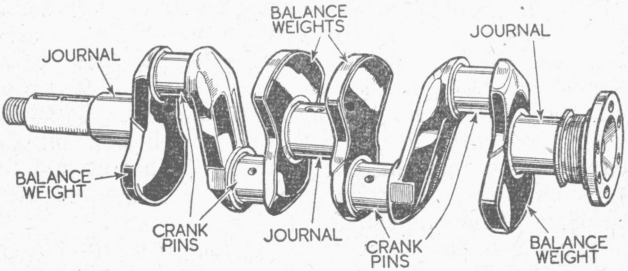
To complete the engine, the casting which forms the cylinder is extended as a case to hold the crankshaft, the camshaft and the drive for the contact-breaker, the case being completed by a lower portion bolted in position so that both crankshaft and camshaft are covered in completely. As a rule, the cylinder is not in one piece, for its head is a separate casting, held to the cylinder by bolts, and can be removed when these bolts are unscrewed.

Now comes the question of bearings. Something has to support any shaft which is driven round, and that something is the bearing, which as a rule is made of metal which causes the least possible friction, and is held in the crankcase. Usually the bearing is made in halves which, fitted together, make a perfect circle round the shaft.

Now, the force of the explosion is considerable; consequently the crankshaft needs to be

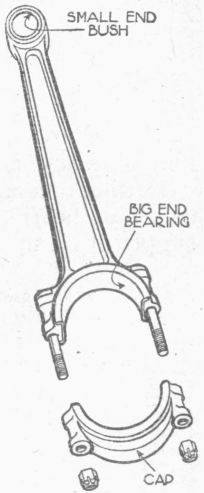


A four-cylinder crankshaft which has three main bearings, one plain, the others roller or ball bearings



A four-cylinder counterbalanced crankshaft with three main bearings showing the attachment for the flywheel in the form of a flange Each crankpin and its webs is called a "throw"

strong. The portion to which the connecting rod is attached is called the crank pin, which is joined to the real shaft by what is called a web, the web and pin forming the true crank. But it is best to have a web at each end of the pin, which in turn means that there is a shaft for each web, consequently a bearing on either end of the crankshaft. With the crank in this form, the rod must be attached to the crank pin also with a split bearing, called the big end.



A typical H-section connecting rod

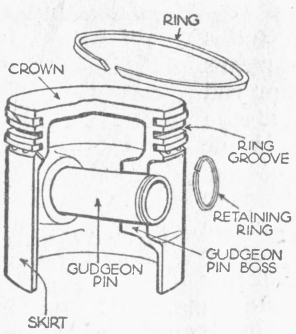
The other end of the connecting rod is smaller and has in it a bearing. The means of securing the piston to the connecting rod is usually a hardened pin called a gudgeon pin, which is passed through a hole in the side of the piston, then through a bearing in the connecting rod, and then into a hole in the opposite side of the piston, the piston being shaped with bosses so as to give the end of the pin ample support. A small ring with a slot in it, much like a tiny piston ring, is then sprung into the holes in the piston and prevents the gudgeon pin from moving sideways. Note that the gudgeon pin really has two sets of bearings, one in the end of the connecting rod and two more in the bosses of the piston.

Now wherever a shaft runs in a bearing, it has to be oiled,

otherwise so much heat would be created that the bearing metal would melt and much damage would be caused. Oil has therefore to be fed to all the engine bearings as well as to the piston sliding in the cylinder. That is most conveniently effected by filling the bottom of the crankcase underneath the crankshaft with oil, and then driving a little pump from the camshaft so that the pump sucks up the oil and forces it through pipes, or maybe passages, in the crankcase to the bearings of the crankshaft.

It is not so easy to get the oil to pass from these bearings to the big-end bearing of the connecting rod. This is usually accomplished by drilling a passage through the crankshaft to meet another passage drilled up the web, which in turn communicates with a third passage through the crank pin. One end of the crankshaft passage picks up oil supplied to the bearing, and one end of the crank-pin passage allows oil to escape to the inside of the big-end bearing. It was soon found that oil naturally escaped from the ends of the bearings as the shaft revolved ; this had the advantage that oil escaping from the revolving big end was thrown all about the inside of the crankcase and was even sufficient to lubricate the piston and the gudgeon-pin bearings.

Further passages have to be created to lead oil to the camshaft bearings, and finally a pipe has to lead a smaller supply of oil up to the rocking levers which operate overhead valves.

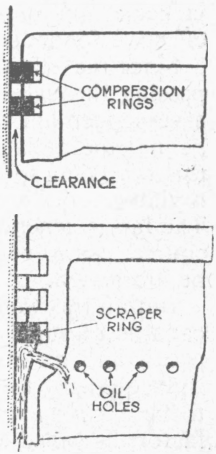


Sectioned piston with circlip retaining device for the gudgeon pin. The second compression ring is shown removed, and the oil-ways, immediately beneath the scraper ring, can be seen

That oil which escapes from the bearings or drains down from the cylinder falls back again into the bottom of the crankcase, and there are even passages from the cylinder head down to the crankcase, so that the oil supply to the rocker gear also returns. Once this oil is back in the crankcase, it is once more picked up by the pump and recirculated.

Since unavoidably there is a certain amount of dirt inside an engine, the oil has to be passed through wire gauze or filter at some point.

It was mentioned that the cylinder had jacket full of water, but this water would ot be sufficient if the engine were to un for a long time. It would gradually each boiling point, and soon after that he cylinder would become much too hot. When it became very hot it would naturally expand, and usually lose its shape, while the unfortunate piston inside the cylinder, which never cools quite so well, because it loses heat only through its contact with the cylinder, would become the hottest part of the engine, expand very rapidly until it became larger than the cylinder, and then could not possibly slide up and down any longer, or, as we put it, it would seize. (Exactly the same thing, by the way, would happen if the oil supply failed, as far as the piston is concerned.) Consequently, there has to be a complete water cooling system.



Details of the three usual piston rings and their purposes. Some engines have more than this number of rings

Somewhere on the car, usually in front, where it will receive all the air displaced by the car's movement, is a series of small pipes connected at top and bottom to water tanks, a small one at the bottom and a much larger one at the top, the whole being called a radiator. A pipe from the cylinder jacket leads the cylinder-jacket water to the top tank of the radiator. A pipe from the lower tank of the radiator is taken to a water pump driven by the engine, and from that pump back to the cylinder jacket. When the engine runs, the pump forces water to circulate from the jacket to the top tank of the radiator, through the many small tubes to the bottom tank, and so round again. But during the passage of the water through the many small tubes, it is cooled sufficiently to be used again.

There is one curious thing about water which is worth remembering—that is, hot water always tends to rise, cold water to sink. In some of the earlier engines the radiator with its tanks was carried quite high up, was in fact the highest portion of the water system, and there was no water pump, because water heated in the cylinder automatically rose to the radiator where, becoming cool, it sank back to the cylinder

jacket ; but unfortunately this has not proved sufficient effective for modern engines.

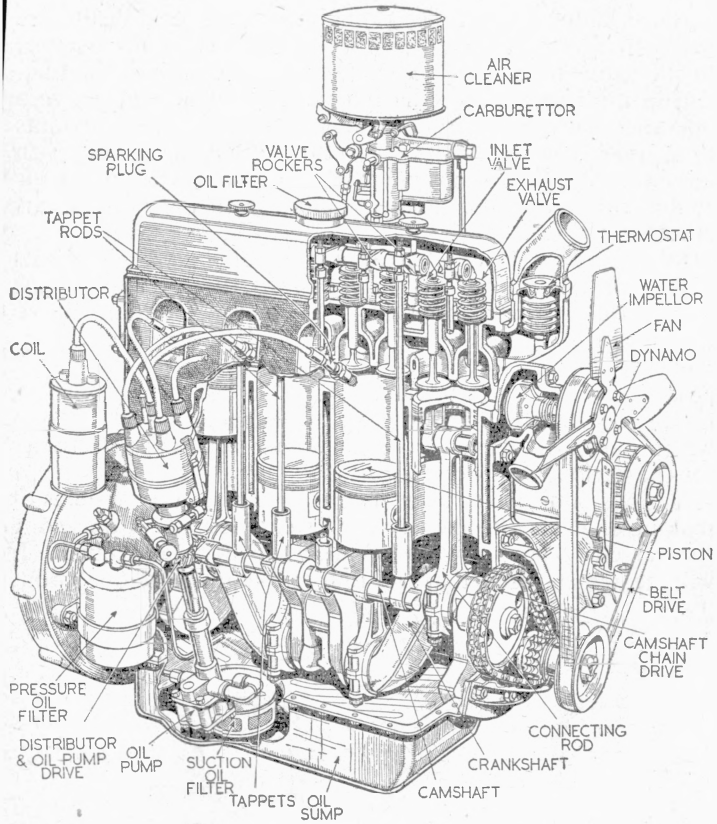
Since the effectiveness of the radiator depends on the a passing through it and because the car might have to clim a very steep hill very slowly, it is also necessary to have a fa behind the radiator and driven by the engine, the purpose c this fan being to draw air fast through the space between th radiator tubes and thereby remove the heat from the wate The fan is generally driven from the crankshaft. The fan, o course, has to be mounted in bearings, which in turn have t be lubricated.

But all this would be of no service without some mechanism capable of supplying to the engine the correct proportion of petrol and air every time the inlet valve opened, and in the right quantity to fill the cylinder. In other words, there has to be a gas factory somewhere near the engine, and the gas factory is called a carburettor.

As a matter of fact this rather complicated-looking piece of mechanism is really quite simple. First of all it has a small chamber into which petrol is fed, and in the chamber a float which cuts off any further supply of petrol when the chamber is full, and opens again immediately more is required. The float chamber therefore stores the exact quantity of fuel automatically.

Petrol from the float chamber is fed to a jet, the nozzle of which is a little above the level of petrol in the float chamber, so that the fuel does not run away all the time. The jet is placed within the pipe leading to the inlet valve. Now when the inlet valve opens and the piston descends, air naturally rushes up this pipe and the effect of air rushing past the jet nozzle is to drive the petrol up so that it sprays through the nozzle and therefore mixes with the air. When the inlet valve closes, the air rush ceases and no more fuel comes from the jet. Of course, the thing needs to be accurate, so the air is caused to move through a restricted passage in the pipe and that restriction is shaped most scientifically, concentrating the suction effect of the air on the jet nozzle.

Remains the necessity to control the amount of gas sent to the engine and so its speed and power, which in turn means that between the carburettor jet and the inlet valve there has to be a throttle, which is a disc on a spindle which, if turned, can close the inlet passage entirely so that neither air nor fuel can pass, or can admit gas in quantities according to how



Section of a four-cylinder car engine identifying major component parts

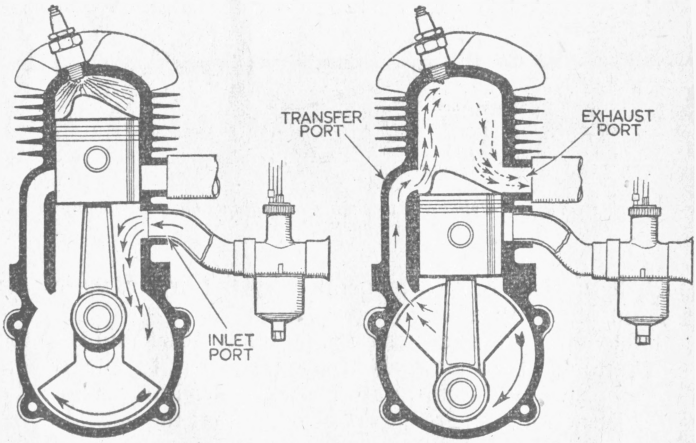
much it opens. A pedal, operated by the driver, varies the position of this throttle.

Refinement has introduced a great many other things to the carburettors. In one type, the air passing to the engine raises a piston in the carburettor. The piston moves a needle in the jet nozzle, the arrangement being that the needle shape permits more petrol to come through the nozzle when the throttle is open wide, while the piston in addition alters the amount of air.

But it happens that a petrol engine needs a great deal mc petrol than usual if it is to start from cold, that is, more pet to the same amount of air, or what is called a rich mixtu and so most carburettors have a special jet which comes in operation only for starting the engine, or even what amour to a very small special carburettor supplying a very ri mixture only for starting purposes, and inoperative when tl engine can take the ordinary mixture from the normal ca burettor.

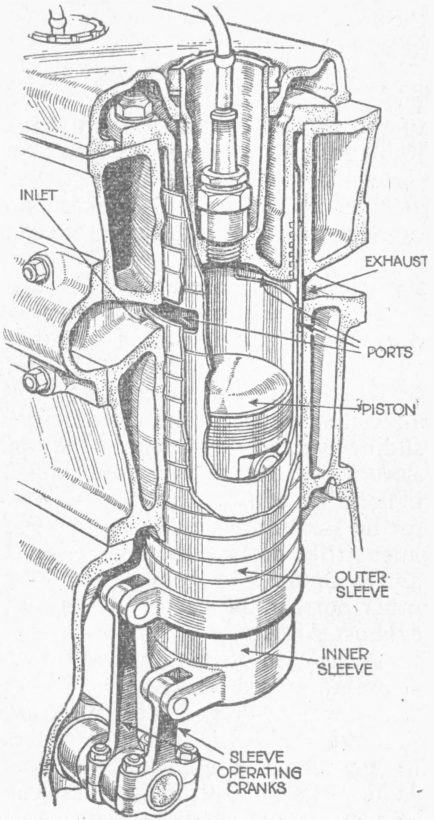
So you have the simplest form of petrol engine, with all i auxiliaries, the carburettor or gas chamber, the inlet and exhau valves, the sparking plug with its contact-breaker and distr butor, as the high-tension portion is called, the water pum the oil pump, the camshaft, the fan. There are other auxi iaries which will be explained later, for instance an electri motor to start the engine in place of the handle and a dynam which has to be driven from the engine to supply electricit for the various needs of the car.

Various efforts have been made to explore other systems o making an engine do the work, different methods of operatin the valves. There is what is called a two-stroke engine. I will be remembered that the four-stroke cycle of operation



Sectional views of the single-cylinder two-stroke engine, showing how the mixture is sucked into the crankcase by the rising piston, to be expelled into combustion space when the piston descends

is inlet, compression, firing, exhaust, and of these only the firing stroke represents work done. In the two-stroke engine, as the piston goes down on the inlet stroke, it uncovers a passage in the side of the cylinder and at the same time compresses gas below the piston in the crankcase, forcing that gas up the passage into the cylinder. When the piston returns, it closes the passage and, travelling further up the cylinder, compresses the mixture, which is then fired by the spark at the plug. The piston is then driven down, and when it has reached a certain point uncovers a second passage, through which the exhausted gases escape. Almost immediately after this, the further downward movement of the piston uncovers the inlet passage and more fresh gas is forced into the cylinder, driving the remnants of the exhausted previous charge in front of it. The top, or crown, of the piston has to be specially shaped to direct the incoming gas in such a way that it will sweep out the cylinder effectively. The upward movement of



A great claim for the sleeve-valve engine is that the shape of the combustion chamber can be symmetrical, since it is not controlled by the necessity for accommodating the valve heads; absence of valve pockets and guides also permitted a better cooling layout. But other factors have proved to be more important in attaining efficiency, and the poppet valve is universal on new cars

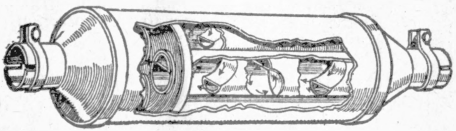
the piston on the compression stroke sucks a fresh charge of gas into the crankcase.

As a result, the downward movement of the piston is the firing and exhaust and inlet combined, the upward movement of the piston compression, so that in two strokes instead of four the work is done. As a rule, however, the engine, which is very simple because it has no valves, is unable to develop as much power as a four-stroke engine because of the difficulty of clearing the cylinder completely of the exhaust gases, and it is difficult to make a two-stroke engine run evenly with the throttle almost closed.

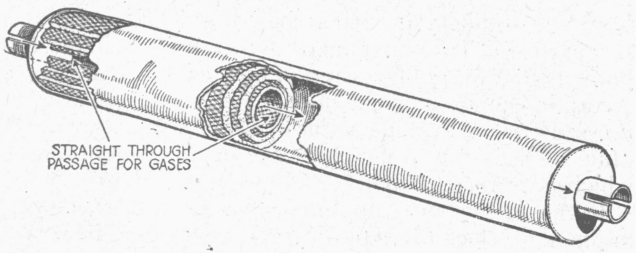
As to valve gear, all sorts of valves have been tried, but the only unusual type which has made any headway is the sleeve valve, which is of two types. The first, which was the Daimler, or Knight sleeve-valve engine, had two sleeves, an inner and an outer, between the piston and the cylinder, the piston sliding up and down within the inner sleeve. Each of these sleeves was operated by the equivalent of a camshaft, usually in the form of a small crankshaft with connecting rods attached to the shaft and the sleeve, the design being such that on the inlet stroke ports in the two sleeves come opposite one another and with the inlet passage, while on the exhaust stroke two other ports in the sleeves register with each other and with the exhaust passage.

A variation of this was the Burt-McCullum, where a single sleeve was used between the piston and the cylinder. This sleeve was made to slide up and down while turning a little, first left, then right, an action which caused ports in the sleeve to register either with the inlet or with the exhaust passages, as necessary. The required movement was obtained by means of a crank driven in the same way as the camshaft.

With both these types of engine one of the difficulties is to prevent the sleeves causing oil to work upwards into the space above the piston in undesirable quantities, for in cold weather oil becomes thicker and if the oil between the sleeves does this, those sleeves become correspondingly hard to move, and consequently the engine becomes hard to start.



Labyrinth form of silencer in which the explosive force of the gases is spent upon baffles. Little back-pressure results from this variety



Straight-through "absorption" type of silencer; acoustically dead material damps excessive noise

The silencer is one of the most difficult features to arrange satisfactorily. It must be remembered that an engine develops its full power only if the used gas can be discharged freely past the exhaust valve to the air. On the other hand, the noise created by this process is practically unbearable, and certainly is illegal. As a compromise, therefore, the exhaust gases have to pass through something which will eliminate as much noise as possible, yet permit sufficient freedom of exit to maintain engine efficiency within reasonable limits.

The practice followed, therefore, is to discharge the exhaust gases into a pipe leading to a cylinder called the silencer, in which the gases are allowed to expand, thereby reducing the amount of noise which will be heard. After expansion the gases are conducted by a second pipe to an exit somewhere near the tail of the car. One type of silencer is packed with certain material, into which the gases are directed. In other words, the gas passes down a pipe until it reaches a point where many holes have been drilled, and through these expands in amongst the packing, which itself is contained in the silencer. In other cases baffles are introduced, causing the gas to pass through many passages before it reaches the exit pipe. The type adopted is the one which will deal most effectively with the situation, and, of course, a great deal depends on whether the engine is at full throttle, for at full throttle there will be much more noise than at half or a quarter throttle opening. Silencers become hot, and must therefore be cooled by air; they also contain a good deal of water, which is condensed from the exhaust gases.

So far, the diesel engine has not been and is not likely to be fitted to the ordinary car. None the less, it is well to explain that there is another type of engine under this name, differing

from the ordinary in that it has no electric ignition and no carburettor. To understand the system it is necessary to know that if the compression of an engine is increased beyond a certain point, sufficient heat is generated to cause the compressed gas to explode without the assistance of a sparking plug. That is the principle of the diesel, the compression for which is extremely high.

If the engine were to inhale gas from a carburettor, the moment at which the explosion occurred would be very difficult to control ; therefore the engine inhales air only, and at the exact moment when firing should take place a measured quantity of fuel is squirted into the combustion space by an injector, which is a mechanism fed with fuel from a small mechanical pump and arranged to seal itself against the explosion pressure. Each injector, and there must be one for every cylinder, is provided with its own pump, the battery of pumps being grouped together and driven by the engine.

It is very necessary that the fuel in the pump and in the pipe to the injectors is completely free from air, equally necessary that the pumps can be adjusted very accurately, so as to provide exactly the correct amount of fuel, a thing none too easy for engines with very small cylinders. Owing to the system under which the engine operates, it is possible to use a much less expensive fuel than petrol, the usual type of fuel being called diesel (or fuel) oil, and this happens to be a slightly unpleasant liquid liable to cause a minor form

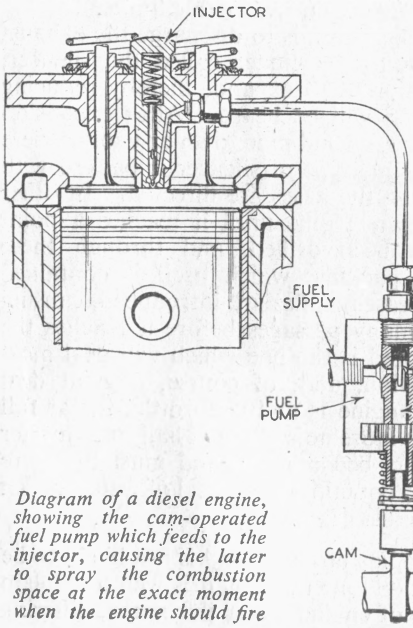
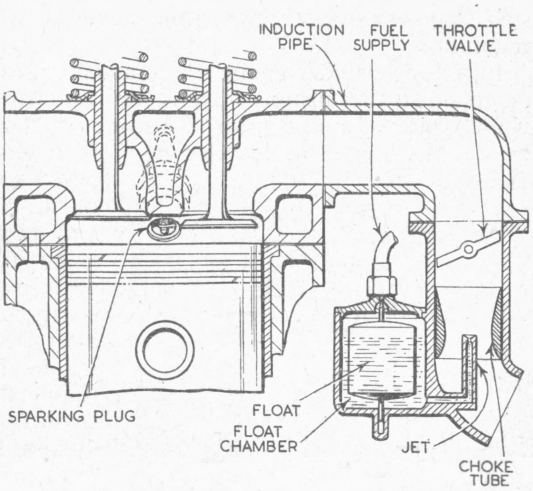


Diagram of a diesel engine, showing the cam-operated fuel pump which feeds to the injector, causing the latter to spray the combustion space at the exact moment when the engine should fire

of blood-poisoning if allowed to enter a cut in one's hand, unless suitable precautions are taken.

So far, the diesel engine generally is run at much lower speed than the petrol engine, and by reason of its very high compression has to be very much more robust to withstand the higher stress.



In contrast to the diesel engine the ordinary car engine sucks mixture from a carburettor and this mixture when compressed is fired by a spark. For this type of engine a much lower compression is neccessary but higher crankshaft speed is possible

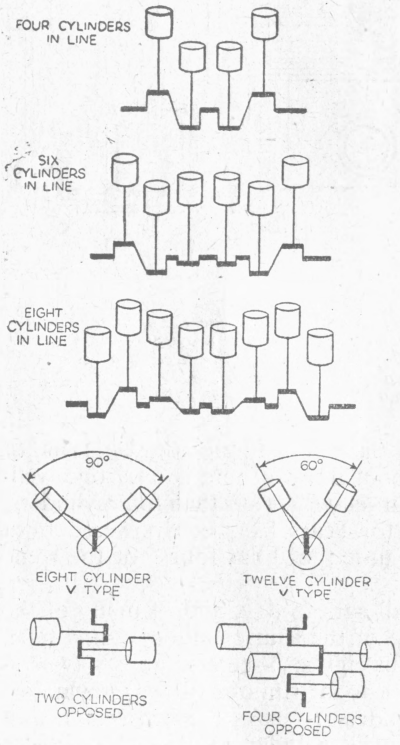
The number of cylinders that an engine possesses is one of the first questions asked about it, and there is only one well-known British car on the market with fewer than four cylinders. This is the Jowett, which for years has been powered by a most efficient " flat twin " unit ; a " flat four " of the same make is also produced.

The engines of most small cars to-day, and of many of the larger machines as well, are of the four-cylinders-in-line type, but there are sixes, straight-eights, V-eights, and V-twelves as well ; with even an occasional rumour of more cylinders still. " Why so many cylinders ? " asks the novice. It will be remembered that the single-cylinder unit has one power stroke and three idle strokes (exhaust, induction and compression) in the two revolutions forming its working cycle. Obviously, therefore, a car propelled with such an engine would tend to progress in jerks.

If there are two cylinders, arranged as in the Jowett, then one cylinder has its power stroke when the other cylinder is on its induction stroke, the result being that there are two evenly

spaced power strokes in the four-stroke cycle, or one in each revolution.

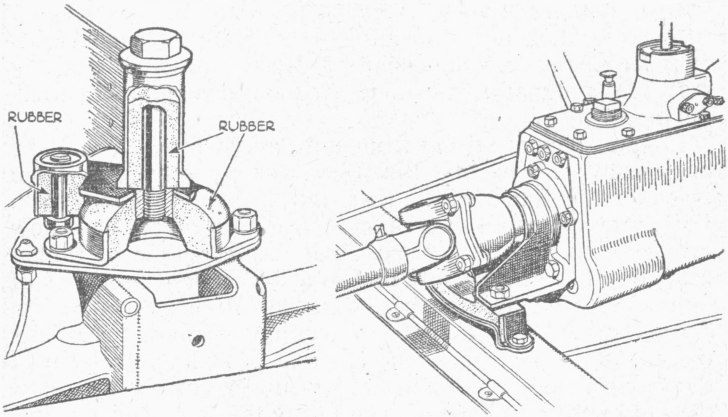
In a four-cylinder engine the crankshaft and camshaft are arranged so that pistons 1 and 4 move up (or down) together while pistons 2 and 3 move down (or up) together ; that is, the cranks are set at 180 degrees. When piston 1 is on its power stroke, piston 4 is on its induction stroke, and meanwhile piston 2 is on its exhaust stroke and piston 3 on its compression stroke. So after piston 1 has had its power stroke it is followed by the power strokes of pistons 3, then 4, and finally 2. The firing order is said to be, therefore, 1, 3, 4, 2. The firing order 1, 2, 4, 3 is also used in certain makes. The power strokes, of course, follow one another in unbroken succession but do not overlap.



The seven types of car engine in use to-day shown diagrammatically in terms of pistons and crankshafts. There are one or two further types, such as the narrow-angle V4, but these are not in common use. The student will find it interesting to think out why the V types (of which obviously only the front set of pistons can be here shown) should require a 90° angle for a V8 and a 60° angle for a V12

In the case of a six-cylinder engine the cranks are arranged at 120 degrees. There are various possible arrangements, but pistons 1 and 6 move together, so do 3 and 4, and so do 2 and 5, and it is usual to have the camshaft arranged to give the firing order 1, 5, 3, 6, 2, 4. In this case the power strokes actually overlap one another.

It will be realised, therefore, that the greater



Examples of flexible mountings for power units, wherein rubber is used to prevent metal to metal contact between mounting and the frame of the car, and a degree of flexibility is introduced, to prevent minor engine vibrations being transmitted to the driver and passengers. (Left) : A forward engine mounting. (Right) : A rubber-cushioned mounting behind the gear box

the number of cylinders the less fluctuation there will be in the power impulses ; the more constant is the torque or turning effort of the engine.

Apart from the smoothness of torque there is another consideration, balance. The term balance is a difficult expression to explain. A moving part in perfect balance causes no vibration ; a badly balanced engine is, therefore, one which vibrates unduly. If a bicycle is lifted and the back wheel is spun rapidly it will be found that the whole machine vibrates. This is owing to the fact that the tyre valve is not counterbalanced by a similar weight on the other side of the wheel.

The wheel is, therefore, out of balance, but this can be remedied by fixing a weight on the other side of the wheel of exactly the same weight as the valve and at the same distance from the centre. In an engine which runs at very high speeds it is very important that every part should be in perfect balance ; the crankshaft, for example. The reciprocating parts must also balance.

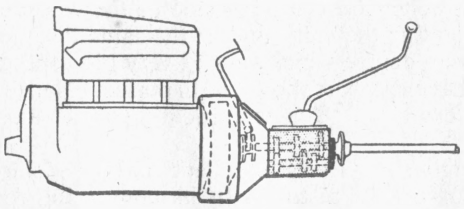
The flat twin engine possesses excellent balance, since clearly the movement of one piston with its connecting rod and crank pin has a counterpart in the equal and opposite movement of the other piston assembly.

It is impossible to go very deeply into this question of balance, and it must, therefore, be accepted that a four-cylinder engine can be balanced reasonably well, but not perfectly, and that a six-cylinder engine is inherently in perfect balance.

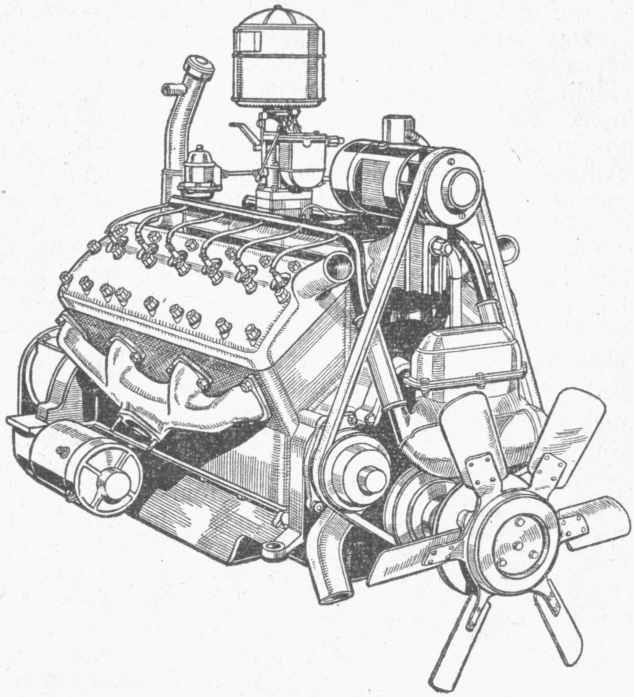
Engine tremors arising from unbalanced forces cannot be completely eliminated. But they can be prevented from reaching the frame of the car and thence the coachwork. Early attempts to insulate the power unit on rubber have now evolved into an exact science, and the technique of rubber mounting has been greatly improved by modern processes of indissolubly bonding rubber to metal. It is now usual to carry the power unit upon, or within, a pair of diagonally placed soft rubber blocks mounted fairly high at the front of the engine, and somewhat similar rubber cushioning below the tail of the gear box, in such a way that an imaginary line from the front to the rear mountings will pass approximately through the centre of gravity of the unit.

Originally engines were built in three main parts. First there was the cylinder barrel and head, a single iron casting separate from the second part, the upper half of the crank case. This latter was frequently of aluminium, as was the third part : the sump, or lower half of the crank case. In the case of side-valve engines, which were the most common, removable caps were screwed into the head in order to provide access to the valves for fitting or attention.

The next development was the detachable cylinder head, an inevitable progression, since decarbonisation with a fixed head was difficult and expensive. From this a further step lay in casting the top half of the crank case integrally with the cylinder block ; still, of course, in iron. This had many advantages, one of the greatest, apart from cheapening manufacturing cost, being the far more rigid and satisfactory crankshaft mounting it made possible. The main bearing webs could be carried across the case and be made



It is now general practice for engine, clutch and gear box to be built as one unit



V12-cylinder Lincoln Zephyr engine, a fine example of American design. It closely resembles the V8 Ford in many respects, such as layout of auxiliaries and the fitting of alloy cylinder heads

to serve the double purpose of carrying the crankshaft and stiffening and strengthening the casting without serious addition to its weight.

Thus the most usual modern system of engine construction is attained ; for the same reason of rigidity and saving of manufacturing costs it has also become a widely-used scheme to adopt " unit construction ". This term refers to the practice of smoothly merging the clutch housing and the gear box into the cylinder block and sump : an arrangement which makes flexible mounting much easier to apply than when the gear box is separate.

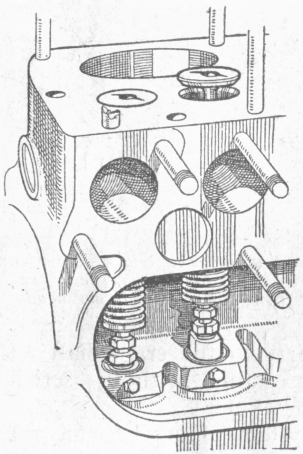
Apart from the horizontally-opposed (flat) type, the engines so far considered in detail have been " in-line ". This kind

of engine becomes fairly expensive to make as the designer, seeking the advantage of many overlapping power impulses, increases the number of cylinders.

The problem is much simplified when a V-type of engine is used. Roughly speaking, the principle of construction in the most widely used V-type is that of two blocks of four cylinders at right angles, operating on a common crank case and shaft. The eight-cylinder Ford is typical, cylinders and crank case forming a single casting.

Obviously the overall length of such an engine need be little more than that of a four. It is, therefore, possible to install the Ford V8 engine in a comparatively short chassis yet retain a roomy body. Of the V12's, fine examples which were built before the war were the 40–50 h.p. Phantom III Rolls-Royce and the Lagonda.

Another type of V engine, the " narrow-angle ", is represented by the Italian Lancia design, which is produced both as a four- and as an eight-cylinder. In each case a one-piece cylinder block is used, with the bores, instead of being in line, staggered and, of course, set at an angle from the vertical, the result being a very compact engine.



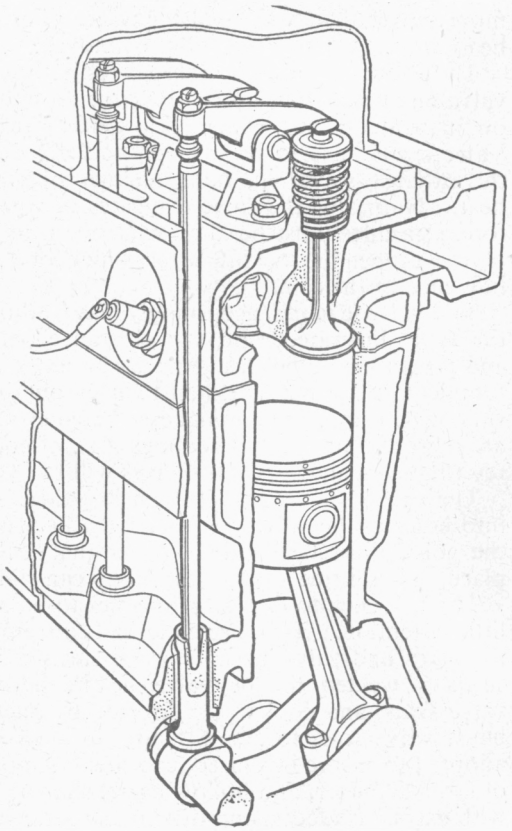
A side-valve layout of popular type. The right-hand valve (inlet) is open, and the tappet can be seen protruding from its guide. Adjustment of valve clearance is carried out by releasing the lock-nut and screwing the tappet head up or down until a feeler gauge of the correct thickness will just pass under the foot of the valve stem; the tappet, of course, must not be raised by the cam

Whatever the form of engine used, some place has to be found for it in the car, and the modern idea is to bring the engine as far forward as possible, so as to reserve the maximum amount of space for the body and seats ; while there is also a distinct tendency to put the engine right at the back, of which more may be heard later.

This, as it happens, was the position in which the engine was placed in most of the original cars, though the arrangement now adopted is very different, but the whole idea underlying it is solely to clear the mechanism

t of the way the carriage-rk, and incidentally to give e driver the dest range of ew possible, stead of ranging a ng and sometimes high onnet straight front of him, ith the engine nderneath the onnet.

During recent ears the tendency has been or the popularity of the ide-valve engine to wane. At one time it vas more reliable, as well as heaper to produce, than the overhead-valve engine. But improvements in steels have made the overhead valve and its mechanism as reliable as any other type, while large-scale production methods have resulted in the overhead-valve engine being as cheap to build.



Long push-rods between the tappets and the valve rocker arms are used in this overhead design. Adjustment is made by the hardened ball-headed screw and lock-nut in the rocker; the ball end rests in a hard steel cup at the top of the push-rod. The feeler gauge is introduced between the end of the valve stem and the rocker arm. Overhead valve gear is invariably enclosed

Overhead valves, moreover, give a more efficient shape of combustion chamber than is possible with side valves, and, therefore, size for size an overhead-valve engine will develop

more power than a side-valve engine. For that reason ov head valves are now generally employed.

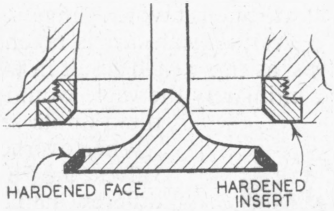
The poppet valve, as used to-day for both side- and overhe valve engines, is mushroom-shaped, ground to a gastight on its seat, against which it is held by a powerful spri Valve steels have to be of a particularly durable nature, the exhaust valves in many engines operate almost at heat. Naturally, the valve elongates as it gets hot and, the fore, clearance must be allowed between its foot and the t of the tappet or rocking lever which operates it under t influence of the cam.

Side-valve engines accordingly have adjustable tappets the type illustrated, and the clearance between valve ste and tappet has to be checked occasionally ; it may be 0·003 for inlet and 0·004 in for exhaust valves, but the actual amour vary widely in different makes of engine. When the valv are reground on to their seatings it is, of course, necessary reset the clearances, for the valves will have descended a littl

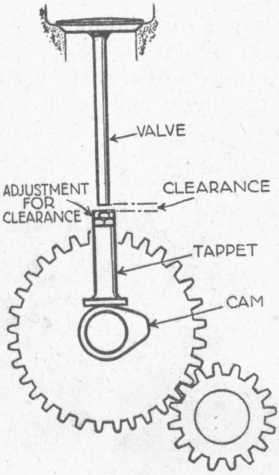
The valves slide up and down in guides which are presse into holes in the valve ports, and the fit of the valve stems the guide must be good, in order that leakage cannot tak place, and yet free so that the valves can slide easily.

The tendency to-day is for engines to be developed needin little attention. This principle is being applied particularl to valves and valve gear. Special steels for the valves, har surfaces welded to the valve heads, hard-surface inserte valve seats, and cool water directed by ducts around the ex haust valve seats to avoid distortion are some of the mean adopted to ensure increased long life. Tappets, too, are mad of large diameter, and hollow barrel shape, of chilled cast iro with extra hard faces, and they are so arranged that the tappe slowly revolves in its guide and so rolls on the cam face reducing wear and spreading lubrication. Yet another featur is the introduction of the self-adjusting hydraulic tappet, whic operates through an oil cushion which automatically adjust itself to take up the clearances, resulting in more silent opera tion.

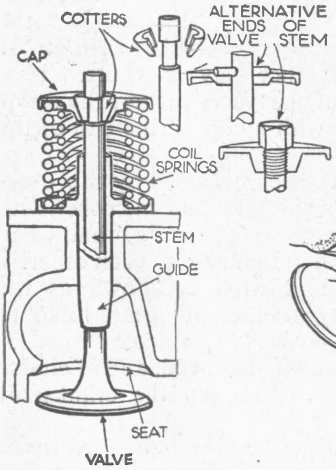
Overhead valves may be operated in one of two ways : b push-rod or by overhead camshaft. The push-rod system i the more popular. In this, the camshaft is located as in side-valve unit, and the valves, set vertically and inverted i the cylinder head, are operated through rockers by long push rods. The overhead design, as its name suggests, transfer



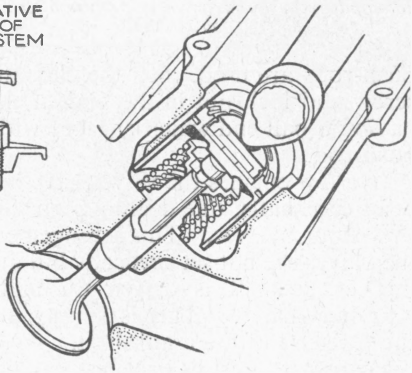
Modern valves are often made with a hard or toughened face, fitting an equally hard or tough seat



(Right) Valve gear in its simplest form, showing also the 2 to 1 gearing of the camshaft

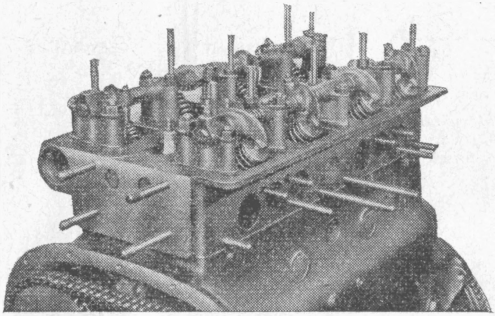


An overhead valve assembly with the parts named, and alternative methods of securing the stem



In this o.h.v. (overhead valve) mechanism cams on an overhead shaft bear directly on plungers in contact with the valve stems. The diameter and length of the plungers and their cylindrical guides obviate side thrust on the valves

the camshaft to the cylinder head, where it may operate the valves in various ways, more or less directly through small plungers or sliding pistons, or through pivoted fingers or rockers. In the design of the operating gear care is taken to minimise side-thrust on the valves, as this would result in wear of the stems and guides, so that ultimately the valve would be tilted on its seat.



Cylinder head of the 2½-litre Riley, the inclined valves being operated by rocking levers, which in turn are actuated by push-rods from camshafts high up on the crank case

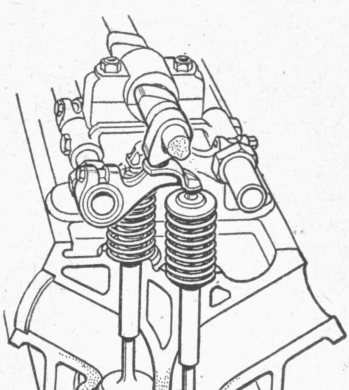
When overhead valves are used different methods of adjusting clearance are involved. The rocking finger may, for example, have an eccentric bush, by turning which the finger is withdrawn a little from the valve stem, thus increasing the clearance. If push-rods are used, then the clearance may be adjusted by a screw and lock nut in the end of the valve rocker, the screw having a ball end which engages with a cup on the end of the push-rod.

In a few engines the valves have been operated by two overhead camshafts, one dealing with the inlet and the other with the exhaust valves. This arrangement is generally found when the valves are not set vertically but at an angle to each other.

The camshaft is driven through what is known as the "timing gear". This is simply a reduction gear, fitted to the fore end of the crankshaft. As was explained on page 13, the camshaft must be driven at half engine speed, and of course an exact relationship must obtain between the crankshaft position and the valve operation.

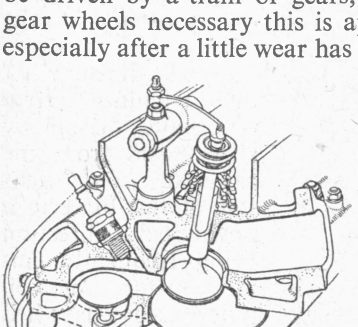
In the case of side-valves or of push-rod-operated overhead valves, either of which require the camshaft to be located low down at the side of the cylinder block, the camshaft can be driven by gear or chain. The earliest timing drives were all-gear but the crankshaft and camshaft sprockets are generally now linked by roller chain.

It is usual for chain drive to have an automatic spring tension device ; in some forms a jockey sprocket is pushed by spring tension into the chain and tends all the time to pick up the slack, while in other cases a spring blade bears on the back of the chain. On many popular cars, however, the shortness of the drive makes a means of adjustment unnecessary. In such cases, however, the chain is usually of the duplex type, that is, a roller chain with two rollers on each pin and a central row of " side plates ".



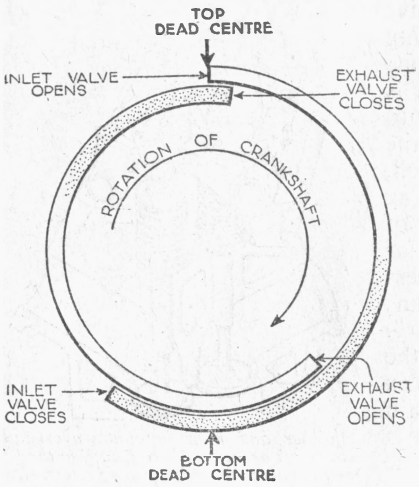
Another and more common overhead camshaft design. To reduce side thrust on the valve stem rockers are interposed between cams and valves

Overhead camshafts may be driven by a train of gears, but owing to the number of gear wheels necessary this is apt to be a very noisy method, especially after a little wear has taken place. Accordingly it is more usual to use a roller chain drive, but owing to the length between the crankshaft and camshaft centres it is sometimes thought desirable to divide the drive into two portions.

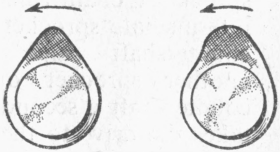


Rolls-Royce cylinder head in section. The design is unusual because one valve is at the side of the cylinder block, while the other is on top of the head, actuated by a push-rod and rocking lever. It will be noticed that the overhead valve has a special valve seat, screwed into the cylinder head and also two separate coil springs

From the crankshaft sprocket a chain runs to an intermediate sprocket on a countershaft and from another sprocket on the countershaft a second chain takes the drive to the camshaft. An automatic jockey sprocket may be used to tension the lower chain and the upper chain may have another form of adjustment, an eccentric bush carrying



The correct timing of the valve gear is of the utmost importance. For the sake of simplicity the kind of diagram shown here is generally adopted, the valves being regulated over one complete revolution of the crankshaft. Usually the opening and closing of the valves is described in relation to the degrees (of the crankshaft rotation) before or after top or bottom dead centre (generally abbreviated to T.D.C. and B.D.C.). There is considerable variation as between one engine and another, and particularly between touring and sports types. The whole object is to allow time for the exhaust to be cleared for the new gas to enter the cylinder



Normal (left) and "quick-lift" cam profiles. The quick-lift profile gives greater power at lower speeds, though at the expense of smooth running. At high speeds "quick-lift" and "high-lift" cams cause considerable wear and tear of valve mechanism, which is the price paid for "performance"

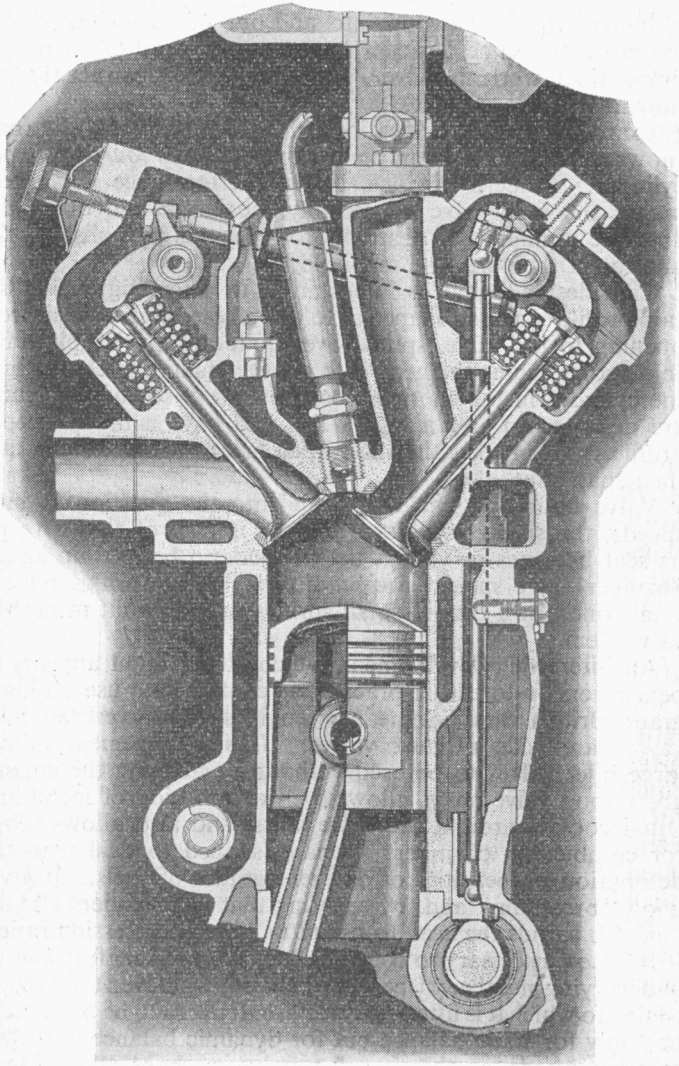
its countershaft sprocket.

Chain-driven overhead camshafts are usually provided with some device in the form of a special sprocket attachment that allows the cylinder head to be lifted without breaking the chain joint or disturbing the camshaft timing.

Another overhead camshaft drive is by means of a vertical shaft with bevel gears or skew gears connecting it to the crankshaft at the lower end and the camshaft at the upper end.

The distributor of the coil ignition system is usually driven by skew gears from the camshaft, a continuation of this drive in a downward direction being frequently employed for the oil pump. Nowadays it is customary to drive the dynamo by the endless rubber and canvas V-section belt that drives the fan and water impeller, if one is fitted.

Whatever the type of operation or the location, the valves all serve the same purpose



Valve gear of the Bristol Frazer-Nash engine, which is unusual because the camshaft is in the side of the crank case, low down, and operates one row of valves by means of push-rods and rocking levers, the other row by means of an additional push-rod which run at an angle across the top of the engine

of controlling the gas flow into and out of the cylinder, a
therefore the same basic principles apply to all of them.
doing their work, however, the valves must obstruct the g
flow as little as possible.

Examination of specifications of bygone giants of the roa
shows that many of them pinned their faith to *four* valves p
cylinder. Modern practice, if high performance is wante
makes the inlet valve appreciably the larger and offers th
absolute minimum of obstruction to the gas by polishing th
interior of the ports and manifold.

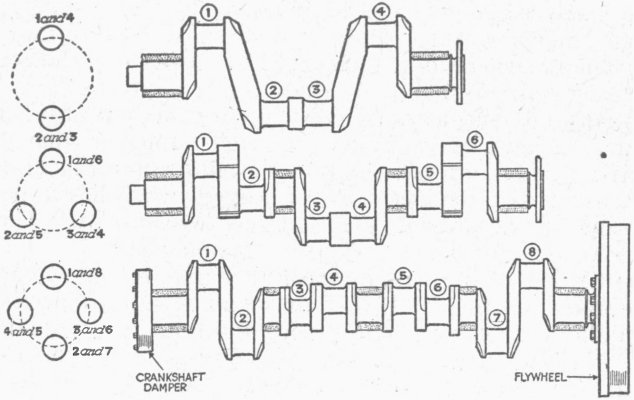
Cam design, again, is important. In a touring engine th
cam profile can be so shaped as to give a comparatively leisurel
opening to the valve, spread over quite an appreciable time
In a sports engine the need is to get the maximum charge int
the cylinder in the shortest possible time ; so that the cam
are designed to give a higher lift, and have a much steepe
profile. This makes the valve open fast to its maximum, an
then snap shut.

Valve bounce is liable to come into the question at high
speed; the springs oscillate, and the impact of the valve on
its seat becomes so violent that it tends to bounce up again.
Stronger valve springs are required: duplex springs replace
single ones, or a ring of small springs may be built round the
valve stem.

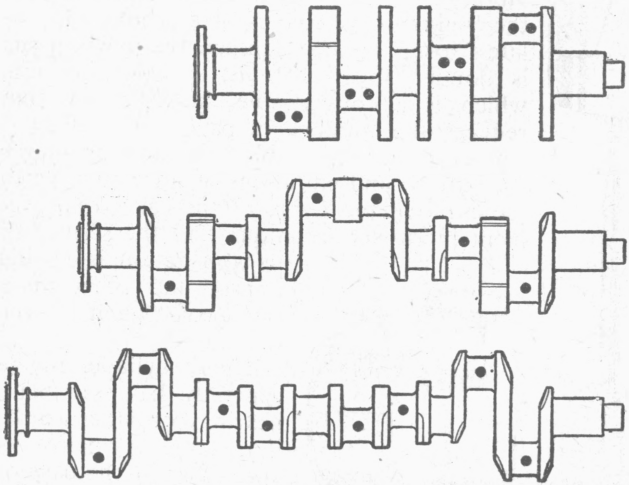
An interesting development, which at first sight appears to
be a reversion to earlier practice, is coming into use on high-
grade British cars. Some new engines have overhead inlet
valves and side exhaust valves. This arrangement allows
large inlet valves to be used without lengthening the engine,
gives good valve ports, allows even distribution of metal and
equal cooling around the valve seats, and also allows scope
for combustion chambers specially shaped to deal with the
detonation propensities of different grades of fuels. It gives
good "breathing" and, by ensuring that the cylinders fill ade-
quately, avoids the need to use ultra high compression ratios.

It is now necessary to consider how the crankshaft is carried
in a varying number of bearings. Also, whatever the type of
engine to which it is fitted, the crankshaft needs to be balanced ;
not only for static balance but for dynamic balance as well—
in other words, so that it will revolve, perhaps at very high
speed, smoothly and evenly. The most elaborate and delicate
machinery is needed to carry out this work.

Most four-cylinder engines have their crankshafts mounted



nd and side views of four-, six-, and eight-cylinder in-line crankshafts, showing he disposition of the crank pins or " throws ". The long eight-cylinder shaft enders desirable a damper, as seen, of which the purpose is to resist the orsional or twisting tendencies of the shaft thereby reducing vibration. The main bearings are shaded

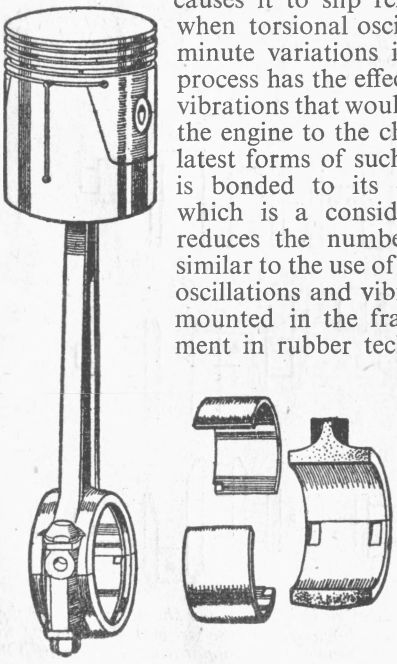


An important factor in crankshaft design is length ; the shorter the shaft the better. In this direction the V8 scores heavily and the straight 8 shows up to less advantage. This illustration shows the comparative lengths of V8, 6-cylinder and straight 8-cylinder shafts, in the order mentioned, from top to bottom. Each black dot represents a big-end bearing

in three bearings, even in the case of really small power units like the Austin Seven. Any crankshaft, however finely balanced, will tend at high speed to " whip " at the centre if it is supported only at the ends.

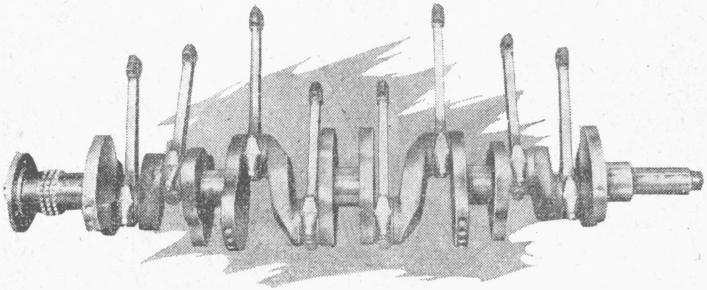
Not only may a crankshaft whip or bend, but, if it is rather long, it may actually twist as well. Imagine that No. 1 cylinder fires, so that the piston begins to push its crank pin downwards ; the inertia of the heavy flywheel has to be overcome, and accordingly the shaft may twist slightly. This may happen even when the engine is running fast, and a device, consisting of a small flywheel to damp out these torsional vibrations is frequently used on six-and eight-cylinder engines. Without this extra flywheel shock vibration occurs at intervals.

A torsional vibration damper consists of a small flywheel at the front end of the crankshaft. It is not rigidly fixed, however, being held between friction discs so that its inertia causes it to slip relatively to the crankshaft when torsional oscillations in the latter cause minute variations in angular velocity. This process has the effect of damping or absorbing vibrations that would otherwise be passed from the engine to the chassis as a whole. In the latest forms of such dampers the flywheel rim is bonded to its disc by a rubber cushion, which is a considerable simplification and reduces the number of parts. The effect is similar to the use of rubber for damping out the oscillations and vibrations of an engine when mounted in the frame of the car. Improvement in rubber technique and the science of its application is having a profound effect upon the development of the automobile.



Flexible steel-backed bearings and low-expansion pistons are widely used nowadays

The six-cylinder engine generally has four main bearings; in other words, the same principle is applied as in the case of the four-cylinder: groups of two big-end bearings, between each main bearing and the next. Some



Daimler 8-cylinder crankshaft with the connecting rods in position. This shaft has five main bearings

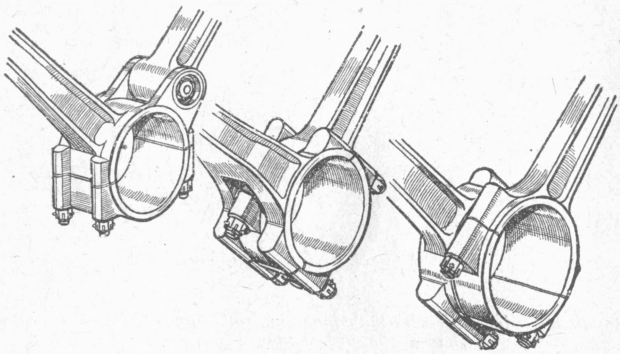
of the more expensive cars have a main bearing between each crank throw, but this is exceptional.

Hitherto it has always been considered that a crankshaft must be forged ; that is, hammered or stamped roughly to the required shape after a plain bar of metal has been heated in a furnace. It is now possible to cast crankshafts from a special quality of steel, which gives improved production facilities.

The V8 type of crankshaft is interesting. Basically it is of the normal four-throw type and is carried in three bearings. Two connecting rods may be arranged side by side on the same crank pin ; a single rod may bear directly on the crank pin while a second rod is hinged to it near the big end, or the two rods may be " forked ". There are pros and cons for each system ; the chief drawback of the first-named arrangement is that the big-end bearings are bound to be somewhat narrow.

Connecting rods diverge widely in design. A favourite for ordinary purposes is plain I-section steel ; high-performance rods are sometimes tubular. The big-end bearing may be a detachable bronze shell lined with white metal, or the white metal may be " run " directly into the end of the steel rods. Another scheme now rapidly gaining popularity is the use of flexible steel-backed bearings, precision-made, which are renewable as easily as piston rings.

The main bearings are similarly steel or bronze shells lined with white metal. Recently there has been a tendency to depart from white metal for big-end bearings, and to use



(*Left to right*) *Articulated, forked and side-by-side mountings for the connecting rods of a V-type engine*

special lead-bronze, nickel-cadmium, or silver-antimony alloys, the reason being that engine powers and speeds are constantly increasing, so that bearings are becoming more heavily loaded.

Pistons are usually made of light alloy ; the iron piston has been completely displaced, save in certain American makes in which an iron piston is " plated " with tin or nickel. For long it was thought that soft-alloy pistons had a " lap " effect on the hard-iron cylinder bore, due to particles of abrasive material becoming embedded in their walls ; modern theory discredits this, however.

Piston " slap ", due to the large clearance desirable with two such dissimilar metals, is now overcome by splitting the skirt of the piston and ovalising its body, so that it expands to true circularity when hot. Of course, this " ovalising " is comparative ; even with bad cases of slap the amount of side-play involved is still only measurable in thousandths of an inch.

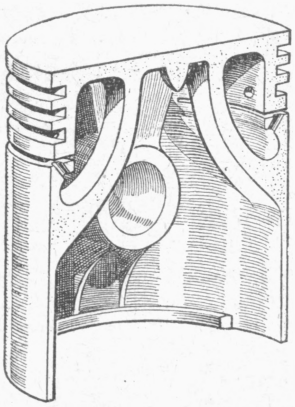
The lowest ring of the modern piston is generally designed to scrape excess oil from the cylinder wall and direct it back to the sump through a row of small holes drilled in the top of the piston skirt. There are never less than two rings above the scraper, and generally three.

Bi-metal pistons have been tried, consisting of an alloy crown, to retain the beneficial heat-conducting property of the lighter metals, and an iron skirt to work at the close tolerance which that material permits.

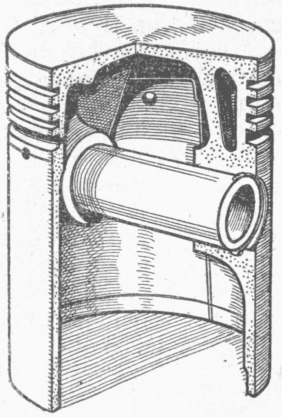
Gudgeon pins are mounted in one of two ways. The most opular is known as full-floating, the pin being a free sliding t in its bosses in the piston and in the connecting rod small nd bush ; a soft alloy pad is fitted at each end of the pin to rotect the cylinder bore from scoring, or else the pin is located ndwise by means of " circlips ". The second method is to ocate the pin at its centre by means of a pinch-bolt and split connecting rod end ; this method throws all the wear due to ubbing movement on to the bearings in the piston bosses, vhich are somewhat less capable of acting as bearings than he bronze bush in a normal small end. The clamped gudgeon in is also rather difficult to fit and replace, particularly in small-bore engines, where it is very awkward to put powerful pressure on to a spanner working inside the piston.

Since the only means of comparing one engine with another n practical fact is to note the horse power developed by the ne against the horse power of the other, it is as well to grasp what horse power really means.

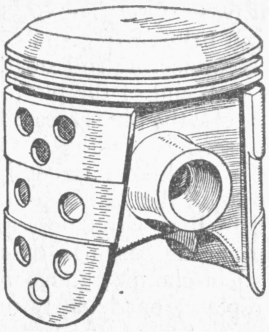
First of all, when James Watt was labouring with his experiments with the first practical steam engines, the only way in vhich he could convey a clear idea of the engines' capability n a horse age was to describe his engines as being able to do



Laystall " Arcaloy " piston with inverted " flying buttress " bracing and semi-floating crown. Note the skirt reinforcement



B.H.B. self-adjusting piston, made in Hiduminium R.R. alloy with split skirt and head supported by gudgeon web extensions



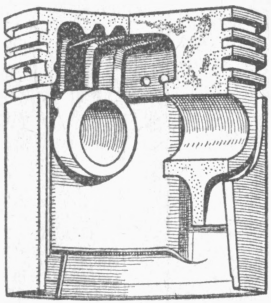
A Ricardo "slipper" racing piston, every possible scrap of surplus metal being removed

the work of so many horses. This naturally led to an attempt to define the work one or more horses can do, and so in the end it was decided that the amount of work done in lifting 550 lb weight vertically for 1 foot in 1 second could be taken as the equivalent of a horse power. Therefore the horse power of an engine is that developed when the engine is tested on a special machine of known and considerable accuracy.

But unfortunately for basic definition the power of the petrol engine varies with the speed at which its crankshaft is running, over a wide range. If the crankshaft is stationary, no horse power is developed. If the crankshaft is running at 5,000 revolutions in a minute, 100 horse power may be developed ; if at 2,000 revolutions in a minute, possibly not more than 30 horse power ; and this complicates the question considerably. None the less, horse power on the testing machine is the only accurate measure of an engine's performance, provided that every part of that machine has been checked properly, and provided that due correction has been made for barometric pressure and for temperature.

But though manifestly it is difficult to assign one stated horse power to any given engine, commercially this is desirable, and so it happens that engines are called 12 horse power although they really develop 75, and other engines are called 12-60 horse power, and so on, a great deal of the trouble being due to a special formula which was evolved some years ago to give a rough approximation of the power of the engine of the period, for taxation purposes.

The usual manner of testing an



Wellworthy compensating piston, a patent design of particular value for fitting to partly worn cylinders, where it will often cure "excessive" oil consumption. It practically fits itself to the worn bore

engine is to make it drive what amounts to a paddle wheel, inside a casing which is full of water, the casing being able to turn in bearings and the mechanism being so designed that the harder the engine drives the paddle wheel, the more the casing will turn. If, therefore, an arm of known length is attached to the casing, and accurate weights attached to this arm, it is possible to register how much weight the engine could lift, and thereby calculate the horse power.

Another instrument is used to show the number of revolutions at which the crankshaft is turning, and the whole is most ingeniously contrived so that for any set number of revolutions the mechanism weight which the engine could lift can be registered. Equally ingeniously, this can be converted into horse power by a very simple calculation indeed.

As a result, engines can be tested, and what is known as the curve obtained, that is, the horse power for every 500 revolutions a minute of the crankshaft can be measured, the measurements placed on paper and connected together by a line, which will necessarily be curved, firstly because the horse power varies with the speed of revolution of the crankshaft, but secondly because, having reached a certain number of revolutions, the engine fails to develop more power.

This is due to a number of things, of which the chief is the difficulty of getting gas into the cylinder in sufficient quantities in that minute period of time during which the inlet valve is open, when the crankshaft is running at 5,000 or 6,000 revolutions a minute, apart from the fact that the hard and extremely rapid operation of the valves causes the valve springs to behave irregularly, so that the valves tend to bounce off their seatings, do not close and open as they should.

A horse-power test is all the more interesting when some modification has been made to the engine in the hope of improving the power, because the two curves, one before, one after the modification, will tell the whole story; similarly, curves taken before and after an overhaul will reveal whether the original power of the engine has been restored or no.

Of course, the power available from the ordinary engine of a production car is not and could not be the maximum power which can be obtained from an engine of that size. Thus a racing engine of nominal 12 horse power may develop 300 horse power and the production engine of 12 horse power 75. The reason for this is, that horse power beyond a certain point

can only be obtained at the expense of durability and reliability, apart from the fact that it is very much more expensive to produce the 300 h.p. engine than it is the 75.

Other things enter into the matter as well. To obtain the 300 h.p.—quite apart from the fact that supercharging would be necessary—the valves must be opened violently, kept open until the last moment, then shut instantly. The exhaust gases must pass quite freely out of the exhaust pipe, because if they do not, they will not clear the cylinder entirely, and the residue will prevent that amount of fresh gas entering.

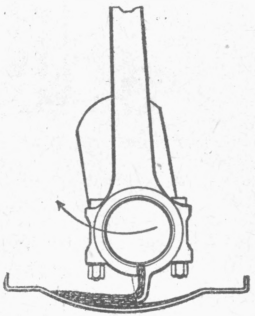
All this means noise, a noisy exhaust and noisy valve gear, two things which would make a production car unsaleable. Furthermore, power is absorbed by friction, therefore more power can be developed if the bearings are reduced to the minimum size, if the pistons have as small an area as is feasible in touch with the cylinders, and if the number of rings is reduced to the minimum. But the smaller the bearings, the less the area of piston in contact with the cylinder, the shorter the life of the engine, and that again would be very serious in a production engine ; while the reduction of the number of rings would lead to oil reaching the combustion space in quantities when the engine was running slow, and that in turn would create difficulties which could not be allowed in a normal car.

It is true that little by little the power feasible from a given size of engine is being raised without cutting down the life of that engine or making it less reliable, but this progress has to be steady, logical and controlled, and has little or no connection with the results obtained from engines designed for racing or records.

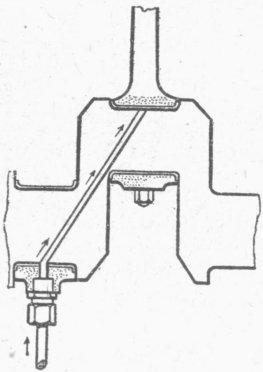
Lubrication and Cooling

THE greatest enemy of power is friction, and a definite elimination of friction would in fact allow perpetual motion to be possible. Elimination, however, being out of the question, the friction in a motor-car engine must be minimised by a suitable lubrication.

It should be understood that the bearing and the shaft, say the crankshaft bearing and its journal, or the big-end bearing and its crank pin, are never actually in contact, for between the two there is, if disaster is to be averted, a thin film of oil. If this oil film breaks down, the heat generated will cause what is termed a seizure, with disastrous results.

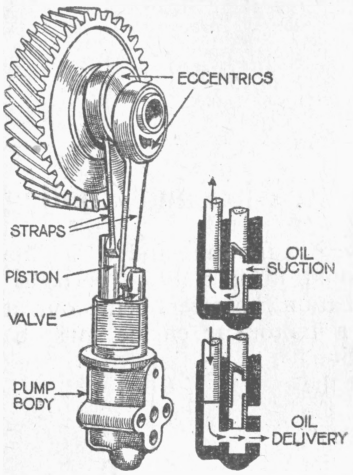


Before pressure lubrication became general, the usual system was to have scoops or dippers on the caps of the big-end bearings. These scooped oil from troughs in the sump as the crankshaft revolved



It is now usual to drill the crankshaft with oil-ways so that lubricant can be delivered under pressure to the bearing surfaces. In this illustration the supply pipe is connected to a main bearing

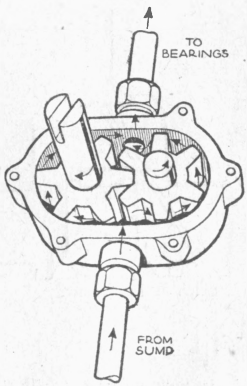
In the last fifty years, engine lubrication has improved out of all knowledge. Commencing with the screwdown grease cap for the crankshaft and connecting-rod bearings, it was then developed so that the big end of the connecting rod dipped in oil once every revolution, splashing that oil into reservoirs which served the bearings, and on to the cylinder wall. The next stage was to place a scoop on the big end and a trough of oil through which the scoop



A plunger pump with a mechanically operated valve. Both working and valve plungers are driven by eccentrics

would travel once a revolution ; and finally it was found best to provide an engine-driven pump, sucking oil from the sump of the crank case, delivering it through galleries or pipes to the main bearings, to the camshaft bearings and to the crankshaft, in which it then travelled down drilled passages to the big-end bearings. Sufficient spray escaped from the big-end bearings to provide lubricant for the cylinder wall and the small end of the connecting rod. Now and then a pipe or passage led oil from the big end to the small end of the connecting rod. Auxiliary feeds were arranged for the timing chain, for the tappets and for the rocking levers when push-rods operated the valves.

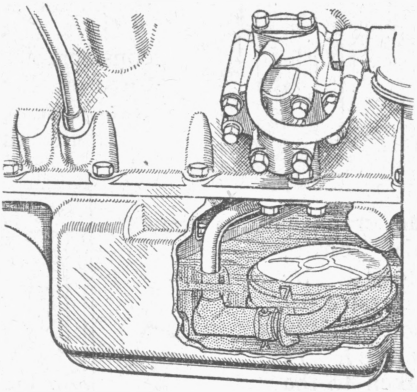
Pressure lubrication of any kind requires a pump. The type used almost exclusively to-day is the one shown in the accompanying illustration, which consists of a casing in which are two gear wheels, one of them being driven from the engine camshaft. The oil follows the direction shown by the arrows and is thereby pumped at pressure to the various bearings. It is naturally essential that the end of the suction pipe should not be uncovered, whatever angle the car and therefore the engine takes. Consequently, the end of the pipe is usually taken down to a well in the sump, and baffle plates round the well prevent the oil from surging away from the pipe under the swing of fast cornering or the angle caused by road gradients.



A typical gear pump : one pinion is driven and the other simply meshes into it. Oil is trapped between the teeth and expelled at high pressure along the main delivery pipe

Since a good deal of dirt and sludge inevitably finds its way to the oil, the pipe is not taken to the very bottom of the ll, and is always guarded by a wire-mesh filter. Occasionly the filter is placed in a float, which maintains the level of pipe always a little below the surface of the oil, the pipe ving a hinged joint to allow for this movement.

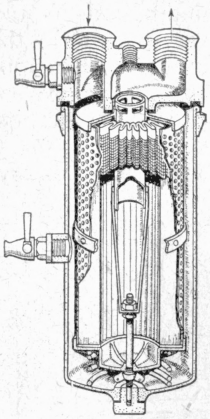
That, of course, is not the only filter which is necessary. ie oil, on leaving e pump under pres-re, is often forced rough a filter amber carried on e outside of the ank case, and conquently through a ie filter, which may e of fabric or what oks like felt. As ie oil is under pres-ire, it can be forced hrough what mounts to a finer iesh than is possible n the suction side, vith far better results a filtration. The ilter chamber is generally arranged so that after a stipulated time it can be opened, the interior filtering unit removed and a new one put n its place.



A type of oil intake in which a cylindrical gauze-faced float rides flush with the surface of the oil, so that lubricant is always drawn from that part of the sump most free from sludge

Further, there is the difficulty that oil, when cooled, is hick, but when hot is thin, so that when the engine is first started on a cold day, the thick oil might cause a very high pressure indeed in the filter chamber, with the result that this chamber has to be provided with a small, spring-loaded valve, set to open when the pressure in the chamber exceeds a certain figure but which closes when the oil, having become hot, assumes its normal viscosity.

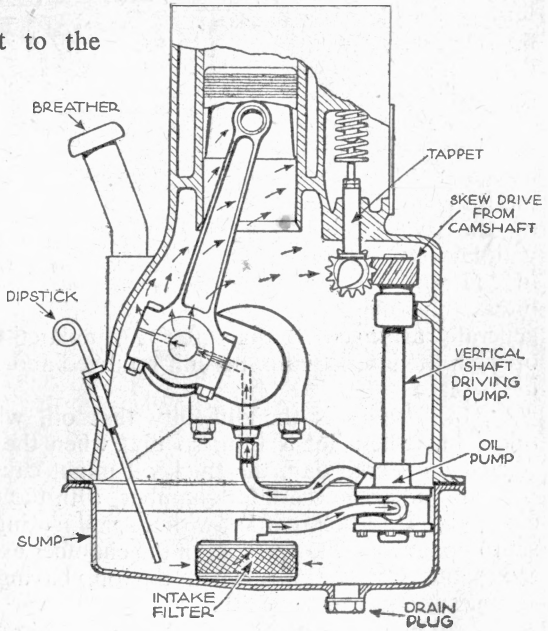
Not all engines are arranged with this filter system. Quite a number have a compromise, which consists of by-passing a certain amount of the main stream of oil under pressure through a filter, instead of transmitting the whole of the oil. In a short time, of course, all the oil in the engine will have



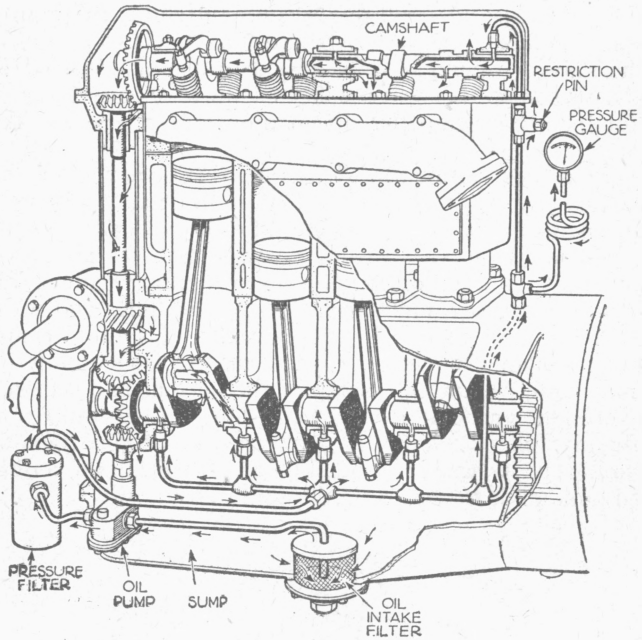
The main pressure filter of a modern oil circulation system. The oil passes in the direction shown by the arrow into the filter, then through the filter element and out again to the engine bearings

passed through the filter under this system, and there is less danger of very high pressure developing when the engine is cold.

There is another difficulty. The considerable pressure necessary to force oil through the galleries in the crank case down to the main bearings and thence through drilled passages in the crankshaft to the big ends, would be excessive for that supply which is taken to the rockers of the push-rod valve gear. Accordingly, the pipe transporting oil to the rockers is led to a small chamber in which a needle valve restricts the outlet hole and so reduces the amount of oil which passes to the valve gear.



A simple side-valve engine with pressure feed to all the crankshaft bearings and arrangements to use splash and mist feed to the camshaft and tappets. An unrestricted "breather" is essential to permit the discharge of crank case fumes which create pressure owing to the heat of the engine



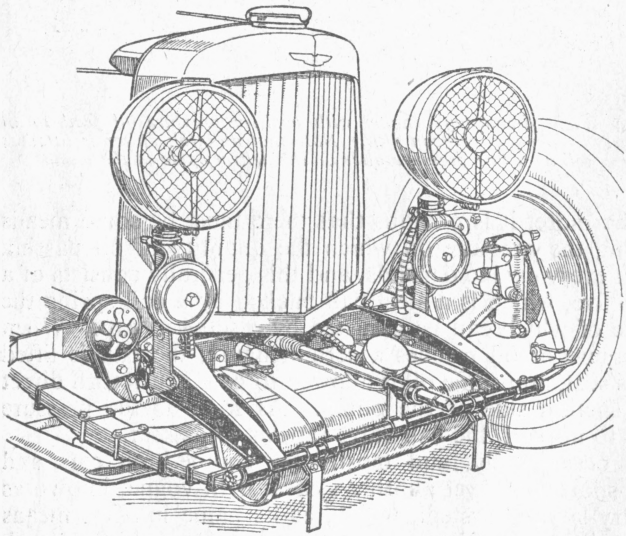
An overhead-camshaft engine with positive pressure oil feed to all parts except the gudgeon pins. Note that an intake filter is fitted as well as a fine pressure filter on the delivery side of the pump

Furthermore, it is obvious that there must be some means of setting the pressure on which the quantity of oil passing through every engine depends, and this generally consists of a safety valve, which is a steel ball backed by a coil spring the pressure of which can be adjusted by a screwed cap. When the pressure of oil reaches a certain figure, the ball is lifted from its seat, and some oil is allowed to pass and return direct to the suction side of the pump. As soon as the pressure returns to normal, the ball valve returns to its seat.

Very occasionally, and mostly for competition cars and certain sports cars, yet another system is in vogue, known as the " dry sump " system, which, as its name implies, means that no oil is stored in the sump at the bottom of the crank case. To ensure this, a second spur gear oil pump is driven in tandem with the main pump, but is of larger capacity, and

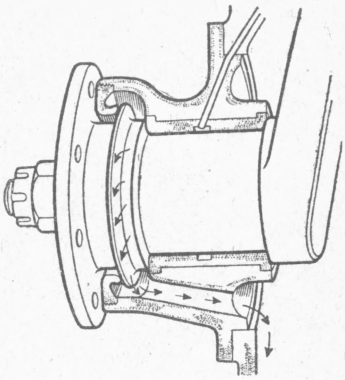
this scavenges, that is, removes all oil from, the crank-c sump as fast as the latter tries to fill. Oil thus picked up the scavenge pump is transmitted to a tank attached to t chassis somewhere near the engine, and it is from this tank a not from the sump that the main-engine oil pump takes supply.

There are certain drawbacks to this scheme, unless it carried out with the utmost attention to detail. Firstly, wh an engine stops, say at the end of a day's work, a good de of oil is still in the various passages and up in the engi generally. This oil drains slowly down into the sump; but t owner of the car might open the oil-tank filler and note th the oil level was low. If he then refilled this tank to capacit the moment the engine started the scavenge pump wou immediately empty the sump of the oil that had accumulat overnight, and could only do so into the oil tank, which already full. Secondly it is of vital importance that the c should be warmed as quickly as possible, and a separa oil tank tends to keep it on the cold side.



An Aston-Martin car with dry-sump lubrication. The oil is carried in a large and accessible tank between the front dumb-irons, where it is well cooled

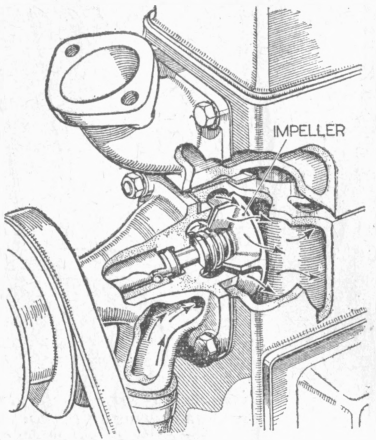
There are a number of detail considerations connected with the lubrication system. First of all, the bearings must all be designed so that the oil can be distributed over their surface quickly, but at the same time so that any sludge or dirt which happens to enter the passages cannot block those passages or damage the bearing. The drilled passages in the crankshaft, for example, are liable at times to collect sludge which would fatally reduce the oil supply. Then, oil must be prevented from leaking down the valve guides into the combustion space ; in other words, the top of the cylinder head where the valves are has to be designed very carefully so that oil escaping from the rocker bearings returns to the crank case quickly and cannot accumulate around the valves.



It is necessary to arrange for the rear crankshaft bearing to be backed with a flange or collar, further sealed on the outer or clutch side by a metal ring. In this way leakage of excess oil is thrown back into the sump as shown by the small arrows

Secondly, oil must also be stopped from escaping where the crankshaft projects from the crank case at the front and at the back, which is usually effected by having a thin circular disc on the crankshaft, so arranged that when the crankshaft is running fast, oil must be thrown off this disc into a channel which leads it back to the crank case. Sometimes, also, the disc is augmented by a coarse thread cut in the crankshaft and operating so that it always tends to drive the oil back into the crank case. Special oil seals, where a rubber-like substance makes a close fit with the revolving shaft, have also been used to ensure that this leakage does not take place.

Finally it is necessary that the owner of the car shall be able to ascertain with reasonable accuracy whether the car's engine has enough oil in it or not. Usually this is accomplished by the rather crude method of withdrawing a highly-polished rod with an ornamental head which will be found projecting from the side of the crank case, so that its end is resting well below the normal level of oil. To ascertain how much oil is

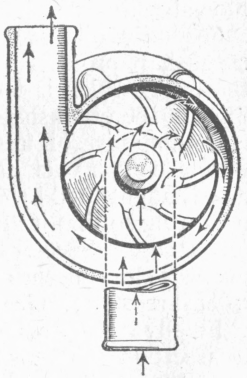


Usually the water pump is housed at the front of the cylinder-head jacket and driven by the fan spindle, as shown in this drawing, the pump being then called an impeller

available, you wipe
rod, put it back and wi
draw it again, whereup
the oil will be found
mark its own level on t
rod. Usually there a
special marks on the r
to show roughly hc
much oil is in place.
late years there is
tendency, however,
provide a float in tl
crank case which operat
electrically a resistanc
controlling the curren
which in turn actuates
needle on a dial. If th
dial has marks to show th
various gradations fron
empty to full, the needl
will indicate the oil level

As already explained, it is necessary for the cylinders to b cooled by water and for that water to be kept in constan circulation by a pump and itself cooled by a radiator. In the modern car the radiator is a series of thin tubes, zig-zagged to obtain sufficient length in a comparatively confined space, and sometimes provided with fins to increase the cooling effect of the air passing between the tubes. The radiator is usually made up into a block which is entirely separate from the ornamental cover which in the past has been mounted in front of the bonnet and is generally of a shape to distinguish the particular make of car. Even this shell is now disappearing, as its real purpose was purely ornamental.

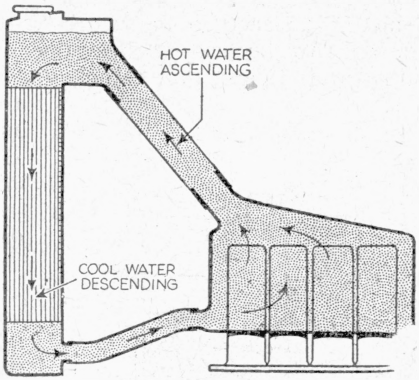
The pump is now a paddle located in a chamber in front of the cylinder jacket and driven by a shaft which is



If the rotor of this pump is driven and water allowed to enter at the centre, that water is forced out through the delivery pipe at considerable pressure

an extension of the shaft carrying the fan, the whole driven by a belt from a pulley on that part of the crankshaft which protrudes from the crank case in front of the engine. As a matter of convenience, this pulley is also used to drive the dynamo, and the dynamo swings on its bracket so as to provide the necessary adjustment. The fan draws air through the radiator, so maintaining the efficiency of the latter when the car is going slowly but the engine fast.

The pump receives water at its centre and forces it outwards by centrifugal action to the cylinder head. The water passages in the cylinder head are formed to ensure that this water reaches the most important points, for example, the valve seats of an overhead-valve engine, and then flows from the head by a top pipe to the radiator, where it is cooled and returned to the pump. Since the engine may be mounted flexibly and the radiator comparatively stiffly, a rubber pipe is used for part of the external water pipe to permit of this movement.



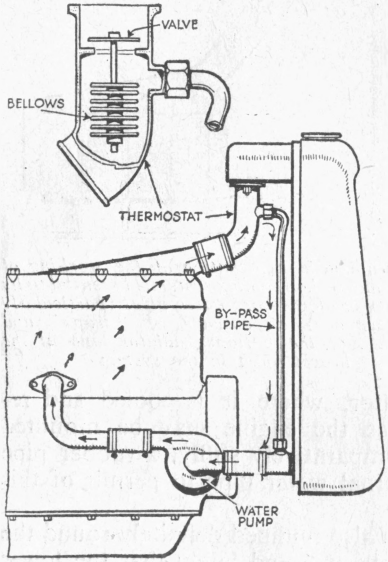
A diagrammatic explanation of the working of the thermo-syphon cooling system. Essential to its efficiency are large-bore water pipes (particularly the upper one), an absence of "traps" and corners, and the bottom radiator tank at the lowest point in the system

In some cases the water is also pumped definitely round the cylinder jackets, but it has been found lately that the lower portions of the cylinders tend to remain too cool, and the more modern idea is to circulate the water through the head by pump, allowing water in the cylinder jackets to circulate chiefly by what is called "thermo-syphon", in other words, to circulate because hot water always rises, displacing cold water, and so forming a natural circulation.

If the circulation system were as simple as this, it would take some time for the water to become really warm when the engine is first started in the morning, and remember the engine

is unable to develop its power unless it has attained a certain degree of heat.

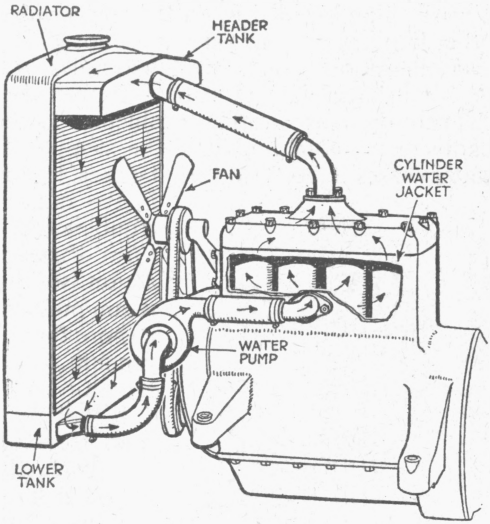
There are two methods of accelerating the speed at which the engine becomes warm, both controlled by what is called a thermostat. The thermostat is a series of small, thin, metal boxes, joined together and so arranged that when they become warm the total length of the assembly of boxes becomes longer, and when cold the total length is shorter. If this nest of boxes is placed in the water, it will expand or contract according to the heat of the water, and if linked to a valve will open and close that valve. Accordingly, the valve controlled by the thermostat may be arranged to shut off the pipe from the top of the engine to the radiator, allowing circulation only through another pipe which goes straight back to the cylinder jackets, by-passing the radiator. With the radiator thus out of action, the water temperature rises more rapidly and the radiator is put in circulation again by the opening of the valve only when the thermostat responds to a certain degree of heat.



With mechanically assisted circulation, whether by pump or impeller, it is necessary to provide a by-pass when a thermostat is fitted, otherwise the effort of the pump will tend to thrust the thermostat open when the engine is cold, and so nullify its purpose. The by-pass is often incorporated integrally in the thermostat mechanism itself. The thermostat here shown is of the type wherein a valve is controlled by the movement of a metal bellows something like that fitted to an aneroid barometer

The difficulty about this system is that on an extremely cold day the radiator might remain out of action for long enough for the water in it to freeze, and so it is necessary either to allow a very limited flow through the radiator or to make the thermostat open or shut shutters placed in front of the radiator to

control the amount of air which can pass between the tubes. With the shutters shut, so little air passes that the water will heat rapidly. With the shutters fully open, the normal efficiency of the radiator is restored. This again has certain disadvantages, in that it takes much longer for the engine to heat, and extra shutters have to be provided ; and it is a matter of opinion which of the two systems is the more efficient.

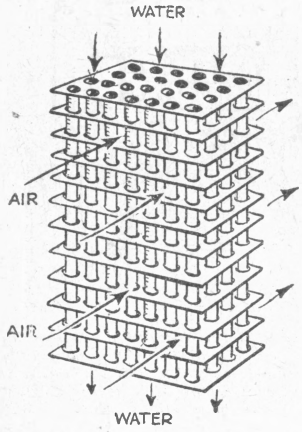


Layout of a four-cylinder engine with pump circulation. Nowadays the true radiator is generally concealed some inches behind a false front, a system which has advantages when repairs are needed, since the plain radiator block is easier and cheaper to handle

There are other considerations. Supposing that a car is climbing a mountain pass, the pressure on the water in the radiator would be less at the top of the mountain than it was at the bottom. That means that it is easier for the water to boil at the very moment when boiling is least required. So in certain cars the radiator is fitted with a spring-loaded valve which will only open if steam generates and will shut immediately the water falls below boiling point. This means that the radiator is running under pressure in certain circumstances, but that makes it more difficult for the water to boil, and incidentally it prevents the constant escape of water as a result of the brakes being used frequently. In the ordinary radiator, a pipe from the top tank allows air to enter at any time and water to escape if the radiator is overfilled. With the radiator water at normal level, if the brakes are used so hard that the car pulls up with a jerk a good deal of water escapes down this

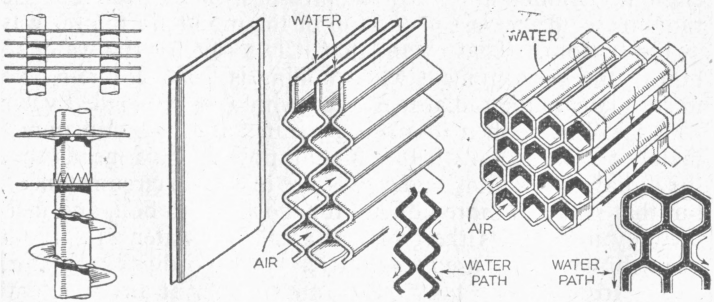
pipe, a thing avoided when the steam valve is fitted. On the other hand, the steam valve does not allow the water to drain away if the radiator is overfilled, unless it is placed in such a position that weight of water will open the valve.

Then there is another problem. If the water does boil badly on a mountain pass, the steam valve opens until the water ceases to boil and then it closes, leaving a partial vacuum in the radiator, which may be troublesome, and the better form of steam valve has a dual action so that it opens under steam pressure but will also open if more than a certain amount of vacuum is created inside the radiator tanks.

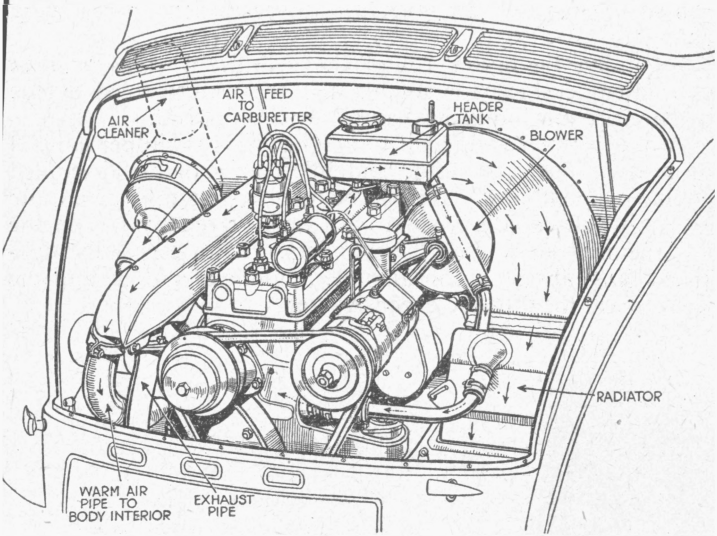


The principle of the radiator is to expose the largest possible surface to the air in relation to the volume of water flowing

It will be noted that water is used for cooling, but water is not absolutely necessary. There are other liquids with a very low freezing point indeed which can be used instead of water as a coolant and which guard against any possibility of freezing in a bad winter. Nearly all these coolants allow the engine to run hotter than it would with water, and nearly all are very much



Some of the methods used in radiator construction: left to right, types of gilled tube, flat (or film) tube, corrugated film tube or false honeycomb, and true honeycomb



Rear engine mounting introduces new cooling problems. An orthodox four-cylinder water-cooled engine is used in this example, and the radiator and air-stream are ingeniously arranged

more expensive and liable to leak away, given the slightest opportunity.

Freezing is a very real danger. If the water in the radiator or in the jackets of the cylinders and head should reach a temperature at which it freezes, the immense expansion caused by the change to ice will almost certainly crack the water jackets or the radiator tubes and tanks. Consequently taps must be provided to ensure that the whole of the water system can be drained, which means there must be at least one tap for the radiator, one for the cylinder water jacket and probably one for the water pump, which otherwise would trap water and be damaged when the owner of the car thought the water system was completely clear and empty.

From all this it may be argued that air cooling is obviously better, but there are very many other considerations. For one thing, it is difficult to control the temperature of an air-cooled engine, since the necessary fins on the cylinder must give sufficient area to deal with the maximum heat the engine

can develop, and are therefore over-efficient on a v cold day.

Secondly, the water round the cylinder acts as a m convenient cushion for sounds and the water-cooled eng is therefore much quieter than its air-cooled rival.

And thirdly, it is difficult to arrange for the proper cont of heat to the carburettor and inlet pipes of an air-cool engine, while it may in the end be necessary to provide a qu elaborate air-cooling system with fans driven by the engi and metal jackets round the cylinders. Fans, especially hig speed fans, absorb a considerable amount of power, and t jackets and the fans are expensive items.

CHAPTER 3

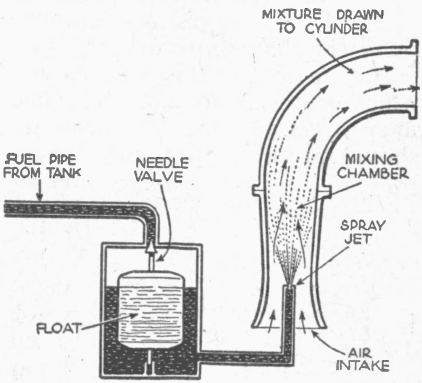
Carburation

IN dealing with the engine reference was made to the mixture of air and petrol which is burnt in the combustion space of the cylinder in order to develop power. In this chapter is explained how that mixture is produced by means of an instrument known as a carburettor, the process of making the mixture being known as carburation.

In order that the necessity for a carburettor may be appreciated, it may be emphasised that the petrol-burning engine is really a gas engine. Many car manufacturers, in fact, run their engines on gas for a certain length of time in testing them. In such cases the fuel, coal gas, is the normal supply from the local gas works. It is mixed with air in the correct proportion for combustion by means of a gas mixer or gas carburettor.

On the road, however, the use of coal gas is not practicable in normal circumstances, although to meet war-time shortages of petrol it was adopted to a limited extent, the gas being carried either at normal pressure in fabric " gas bags " or at very high pressure in steel cylinders. But motor cars are designed for use with liquid petrol, which may be conveniently carried in a tank, and which, by means of the carburettor, may be atomised and mixed with the correct amount of air to form a combustible gaseous mixture.

The earliest method of producing what may be termed petrol gas was very simple. Petrol is volatile, that is, it



How the " scent-spray " principle is applied to the parts of a carburettor

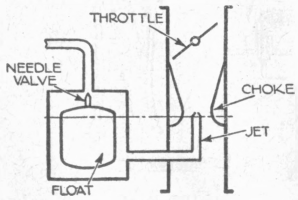
readily gives off vapour when exposed to the air, and the pet used in the early days of motoring was more volatile than tl now available. Accordingly, some of the air drawn in by t engine was made to bubble through the petrol in a tank tl was designed to provide a relatively long path for the through the fuel, which also exposed a considerable surfa area. The air thus became charged with petrol vapour. Tl arrangement was known as the surface carburettor. A var tion of this method employed a series of wicks supplied wi petrol, so that air was drawn in over the wick. This w known as the wick carburettor.

Modern carburettors are of the spray type, and their actic is similar to that of a scent spray, in which the rubber ba when squeezed, forces air through a nozzle which is locate just over a smaller tube or jet passing down into the sce container. The rush of air over the top of this jet causes tl scent to issue from it as a fine spray.

In the carburettor the rubber ball and nozzle are replace by a length of pipe into which the jet projects. The jet kept supplied with petrol, and the rush of air drawn in throug the pipe as the piston descends in the inlet stroke similarl results in a fine spray of petrol from the top of the jet.

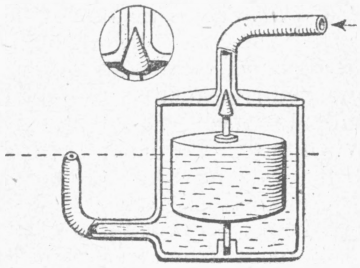
It may be well to consider how this actually happens. O the induction stroke the piston descends and the inlet valv is open. Atmospheric pressure, that is, pressure due to th weight of the air, nearly 15 lb per square inch, causes air t rush in through the inlet pipe and valve to fill the space lef by the descending piston, and this process is loosely describec by saying that the piston has " sucked in " air.

Having grasped this fact, that it is the atmospheric pressure which causes air to enter the cylinder, it can be more readily understood why the column of air passing through the pipe should take a supply of petrol in the form of a fine spray from the jet. If this pipe is connected to the inlet passage of the engine there will be a fall of pressure within it as the piston descends. As the jet is within this pipe, the petrol in it will also be subject to the reduced pressure. The supply of petrol to the jet is, however, under atmospheric pressure, and so the difference



Simple carburettor in its complete form

:ween the pressure in : pipe and the atmos- eric pressure on the el supply will cause trol to be forced out of e jet. This is the inciple of the modern ray-type carburettor. It was found that by aking the interior of the pe a certain shape the ll of pressure within it ›uld be increased, so ıusing more petrol to issue from the jet. For this reason ıere is placed in the pipe, or mixing chamber of the carburettor, hat is termed a venturi tube, more commonly known as a ıoke tube. This tube gradually gets narrower and then idens out again, and the jet is located at the narrowest part f it, where the fall in pressure, or depression, is the greatest.



The petrol level operates a shut-off valve as it rises

As the power of the engine naturally depends upon the uantity of mixture admitted to the cylinder, some method of overning this is necessary. Accordingly, a simple form of ap is placed in the mixing chamber, between the jet and hoke tube and the engine. This tap is known as the throttle, nd it is frequently of the type known as a butterfly. This is nerely a disc of metal, like a penny, fitted on a small shaft, or pindle, pivoted in the walls of the mixing chamber. When he shaft is rotated so that the disc lies across the bore of the :arburettor, the throttle is closed, as it will then blank off the ›ore of the mixing chamber. Similarly, it will be open when :he shaft is rotated so that the disc lies flat in line with the air ;tream, so allowing the mixture to pass around it.

The next point for consideration is the manner in which the fuel is supplied to the jet so that it shall always be full of petrol and yet not overflow when the engine is not running. This is effected by a simple automatic mechanism very similar to that used in the water system of every house. In order to keep the hot-water boiler supplied with water at all times, there is somewhere high up in every house a tank with a ball tap.

The mechanism of this must be familiar to many, but, for the benefit of those who may not be very clear on the matter, it may briefly be described as a hollow copper ball on the end

of a rod which is pivoted at the other end to the side of the tank. The copper ball floats on the surface of the water and therefore rises and falls with it, and the lever to which it is attached is pivoted to a tap which is operated by a push-and-pull movement instead of by the usual turning movement. When the water reaches a certain height, carrying the ball with it, the lever pushes in the tap and the flow of water into the cistern ceases. When water is run out of the tank the ball falls and the tap is opened until the level is restored.

As space is limited in the carburettor, a more compact arrangement is adopted, but the principle on which it works is the same. In a small circular reservoir, the float chamber, connected to the foot of the jet, there is a hollow brass float, which, as it rises, forces a small pointed piece of metal, known as a needle valve, into a seat in the lid of the float chamber. The petrol pipe is connected to the lid in such a way that when the needle valve is on its seat petrol cannot flow into the float chamber.

The float and needle valve are so arranged that the flow of petrol is cut off just before the level is high enough to cause fuel to overflow from the top of the jet. When the engine is running and fuel is being used, the level of petrol in the float chamber falls and, as the float descends with it, the needle valve opens and more petrol flows in.

To explain the working of the float and needle valve, one of the simplest forms has been chosen and illustrated, but many of the older carburettors had a different arrangement, the petrol pipe being attached at the bottom of the float chamber where the needle valve was situated. In order that the upward motion of the float as the petrol rises might give a downward movement of the needle to shut off the supply, two small levers were pivoted to the under side of the float chamber lid, their inner ends engaging with a collar carried on the stem of the needle.

The outer ends of these two levers were weighted to counterbalance the needle and hold it off its seating. As the float rises, it comes in contact with the outer ends of these levers and moves them upward, so causing the inner ends to push the needle downward.

Just as there is much variation in the design and arrangement of the various parts of the engine, so there is much diversity of detail in different carburettors, both in the design of the float chamber and needle valve, and in the arrangement of the

jet and mixing chamber. In addition to the horizontal mixing chamber there is also a vertical type, and frequently a special jet is used in order to give easy starting and slow running. In such a case the slow-running jet goes out of action as the throttle is opened to bring the main jet into use.

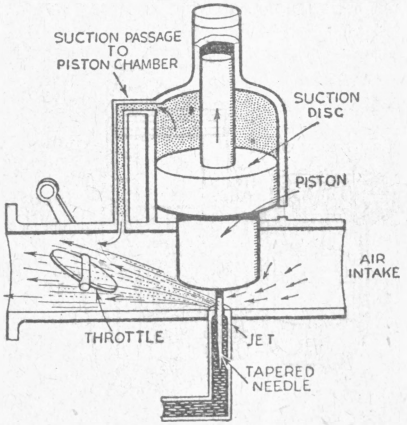
Simple as the principle of the spray carburettor is, its application is by no means easy, for the atomised petrol is much heavier than the air with which it has to be mixed and, therefore, a sudden opening of the throttle is apt to result in too much air being drawn in for the amount of petrol delivered by the jet. Actually, fourteen to seventeen parts by weight of air are required for one part of petrol, and the ideal carburettor would keep the mixture within these proportions, irrespective of engine speed and other conditions.

It is for this reason that there is so much variation in the detail arrangement of the well-known carburettors, and in some cases a number of jets may be used, each situated in its own small choke tube and arranged so that as the throttle is opened one jet after another comes into action. In other cases the size of the jet orifice is varied by means of a needle sliding within it, but the underlying idea of these variations is to maintain a correct mixture at all times.

There are various methods by which corrections or alterations of mixture strength may be obtained. Obviously, alteration of the relative sizes of jet and air intake would allow the mixture to be varied. This is, in fact, the method that is followed in the S.U. carburettor.

In this there is, above the jet, a chamber in which slides a suction disc which incorporates above it a guide to centre the disc, and below it a piston sliding in what may be termed the mixture chamber itself.

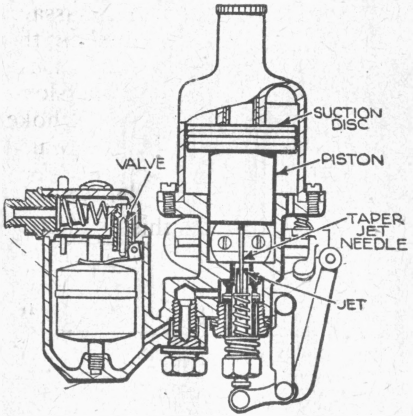
The piston carries a taper needle which



A type of carburettor in which the jet aperture is varied automatically by suction. The disc throttle is also shown

passes into the jet, so that as the suction disc rises the needle is withdrawn from the jet and thus the annular orifice becomes larger. When the suction disc is at its lowest position the thickest part of the needle lies within the jet orifice, which is therefore at its smallest, while when the suction disc is at its highest point the thinnest part of the needle is in the jet orifice which, accordingly, is at its maximum. The chamber in which the suction disc slides is connected through a hole in the piston with the mixing chamber, so that the depression existing therein is communicated to the upper side of the suction disc, and the latter therefore rises and falls according to the depression in the mixing chamber since its under side is subject to atmospheric pressure.

The result of this is that the size of the passage through the mixing chamber, that is, the choke, is automatically varied by the movement of the piston below the suction disc. As the piston, by virtue of the taper needle it carries, also controls the size of the jet orifice, it is only necessary to calculate the desirable taper for the needle to have the correct mixture ratio for the varying depression in the induction system. For easy starting a rich mixture is obtained by lowering the jet slightly by means of a simple control. This brings the jet orifice lower down the needle and therefore enlarges the jet area, and when the engine is started the jet is returned to its normal position.

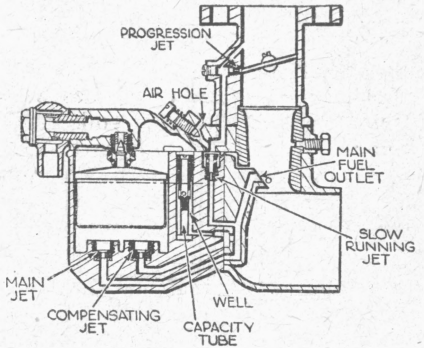


Sectioned S.U. carburettor, showing the jet, tapered needle, and the piston and suction disc which vary the size of the choke and of the jet orifice

In the Zenith carburettor a system of compensated jets is used in place of a simple single jet, and these jets are, moreover, submerged. Actually they are located in the bottom of the float chamber, and they regulate the flow of petrol through ducts which lead to the mixing chamber and main fuel outlet.

With these fuel ducts there are connected

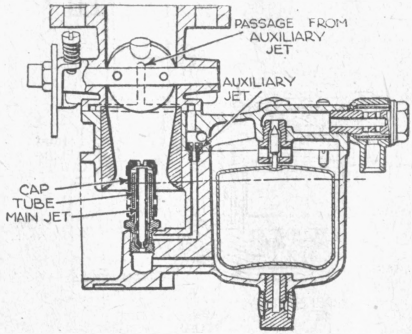
other fuel passages, in one of which there is located a slow-running jet, to which air is admitted through a passage which can be adjusted by a screw, while the other passage forms a small well in which there is a "capacity tube" which regulates the amount of petrol in reserve in the well, the top of the well being open to the atmosphere. From the slow-running jet a passage runs up the side of the mixing chamber to the progression jet, which is just in line with the edge of the butterfly throttle when it is closed, and the passage also continues and comes out into the mixing chamber above the throttle.



In the Zenith carburettor a combination of jets is used to give the requisite variation of mixture strength

When the engine is running slowly, and the throttle is closed, there is a strong suction on this passage above the throttle, and this is accordingly communicated to the slow-running jet through which petrol is drawn from the passage beneath it, while air enters through the hole regulated by the screw. As the throttle is opened the progression jet is uncovered and allows more mixture to be drawn from the slow-running jet, while the suction is communicated to the choke tube, and therefore to the outlet of the main petrol passage, from which petrol is drawn to mix with the main stream of air now passing up through the choke. While this is happening the petrol in the well flows back to augment this main fuel supply, so giving the necessary mixture for rapid and smooth acceleration.

As the throttle is opened fully the subsidiary passages are emptied, and fuel is drawn entirely from the main passage opening into the choke, fuel passing through both the main and compensating jets. But the petrol from the latter is mixed with air passing in down the well, and thus helps to atomise the petrol from the main jet where the two passages meet, so that the fuel is already well split up and mixed with air when it issues into the main air stream in the choke tube.



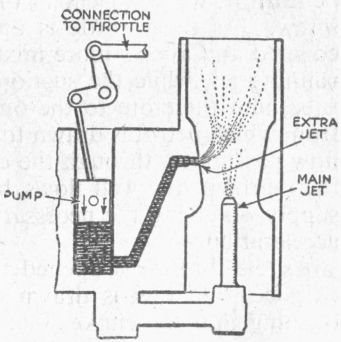
Two jets are used in the Solex and the main jet is surrounded by a tube and cap

For easy starting from cold the slow-running arrangement becomes in effect a small secondary "rich mixture" carburettor, which is brought into action by operating the main air intake strangler control on the dash.

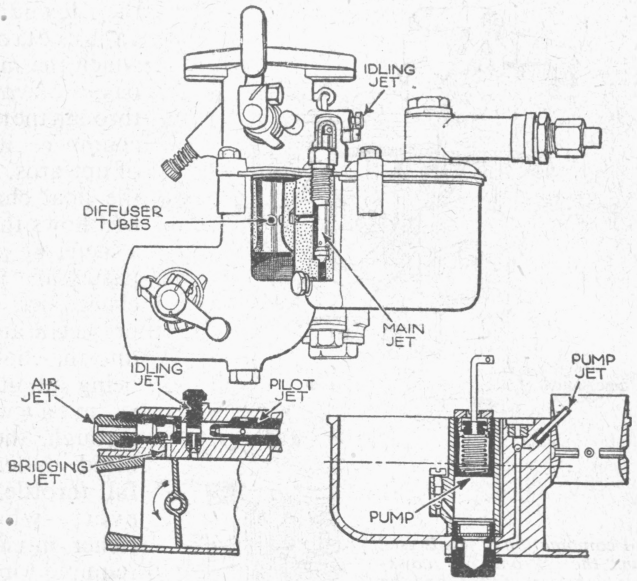
An auxiliary carburettor is also incorporated in the self-starting Solex carburettor, and this has a fuel jet and an air jet of correctly chosen size for the capacity of the engine. The main carburettor has two jets, and of these the main jet is of special construction and is surrounded by a tube and a cap in such a manner that air can enter the cap and pass through lateral correction holes in the jet proper so as to mix with the fuel. There is also an auxiliary jet for idling and slow running, the air supply to which can be controlled by a regulating screw.

When the engine has been started on the auxiliary starting carburettor it continues to run on the mixture supplied by the auxiliary jet and its air inlet, the throttle being closed and the mixture issuing through a duct in the body of the carburettor. As the throttle is opened the main jet comes into action, and so progressively do the lateral correction holes in it.

In the Amal vertical pump carburettor there is a small pump which, whenever the accelerator is depressed quickly, forces petrol through the pump jet into the choke, so



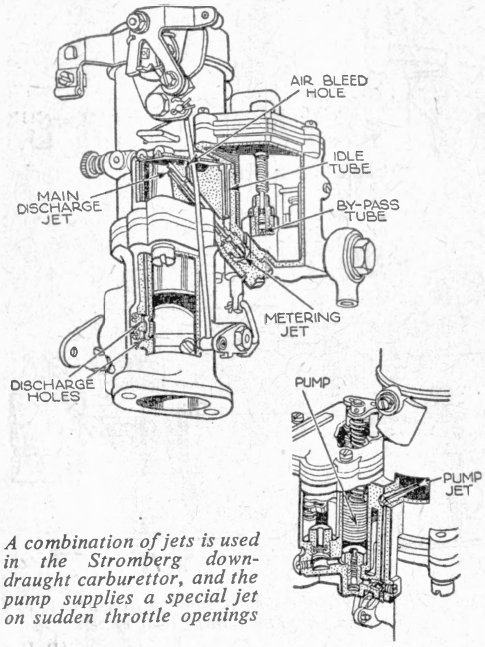
Some carburettors are fitted with an accelerating pump, giving an extra spray of fuel when the throttle is opened. Note the position of the choke, or narrowing of the tube at the main jet



The Amal is another carburettor employing a combination of jets and pump to give extra fuel on sudden throttle openings

correcting the mixture should the throttle suddenly be opened at low engine speeds—that is, when rapid acceleration is required. When the engine is idling with the throttle closed, petrol passes through the pilot jet and enters the mixing chamber through the idling jet just above the butterfly throttle, and as the throttle is opened slightly the bridging jet comes into action and supplies mixture through a small hole just below the throttle thus "bridging over" the period between the pilot jet and the main jet. The main jet is in a passage at the side of the float chamber, and fuel passes through it and mixes with air entering through a hole at the top of the jet, the rich mixture then flowing into a passage to emerge through holes known as diffuser tubes in the choke.

A pump is also a feature of the Bendix-Stromberg carburettor. This also is of the type in which mixture correction is accomplished by a combination of jets and small air inlets known as "air bleeds". Perhaps the best-known model is



A combination of jets is used in the Stromberg downdraught carburettor, and the pump supplies a special jet on sudden throttle openings

the downdraught carburettor, in which the mixture passes downwards through the mixing chamber instead of upwards. From the float chamber fuel flows through a metering jet and passes up the discharge jet, which projects at an angle into the choke, air being admitted to it meanwhile through the air-bleed hole. At full throttle, however, when a richer mixture is required for maximum power, the action of opening the throttle fully also opens an economiser valve in the float chamber, allowing extra fuel to meter through the by-pass jet.

For idling and small throttle openings fuel is taken from the delivery side of the metering jet and passes through a restriction at the base of the "idle" tube, up through this tube, along a horizontal passage, meeting air admitted by the idling air screw, and then passing down to the two discharge holes close to the throttle. The pump is connected to the throttle, and when the latter is opened suddenly to give rapid acceleration, fuel is forced into the mixture through the pump discharge jet, which projects horizontally into the mixing chamber above the choke tube.

Most carburettors are now also made in downdraught form, and the theory underlying these is simple. It is weight of mixture that is important in giving power, and in drawing this weight of mixture up through the carburettor work has to be done, since the weight has to be lifted. In the downdraught carburettor, where the weight of mixture is passing downwards,

: force of gravity is of assistance in the passage of the xture into the engine.

In the Claudel-Hobson carburettor a combination of jets used, and the slow-running jet is surrounded by a diffuser be and is located in a well above the main jet. Connecting th this well there is another well, in the bottom of which is e power jet, there being at the top of this second well a small ring-loaded valve known as the power jet valve. There is so an air inlet nipple.

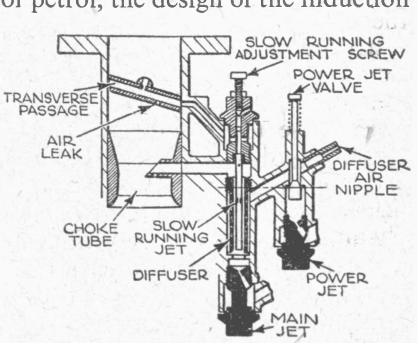
When the engine is idling, the butterfly throttle valve is osed and mixture is drawn from the slow-running jet through transverse passage in the throttle itself. As the throttle is pened, mixture is drawn from the outlet projecting into the ioke tube, air from the air inlet nipple passing through the iffuser tube to mix with the petrol in the main jet well to give partly atomised rich mixture to meet the main air stream.

At full throttle the power jet is brought into action, as a nger or plunger on the throttle spindle depresses the power :t valve, and allows petrol to be drawn past it to mix with air oming through the diffuser nipple, this rich mixture then ugmenting that drawn from the main jet. On some sizes an ccelerating pump is fitted to give a momentary excess of fuel f the throttle is opened suddenly.

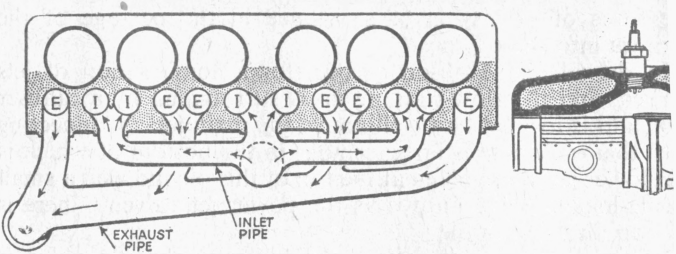
The foregoing is intended to give an idea of the working of arburettors, but it cannot claim to deal thoroughly with the ubject of carburation, which must perforce include such mportant factors as the amount of heat desirable for vapo-ising the minute globules of petrol, the design of the induction manifold, the shape and sizes of valve ports, and even the shape of the combustion chamber.

As to the induction manifold, this is simply a means whereby one carburettor is made to serve two or more cylinders.

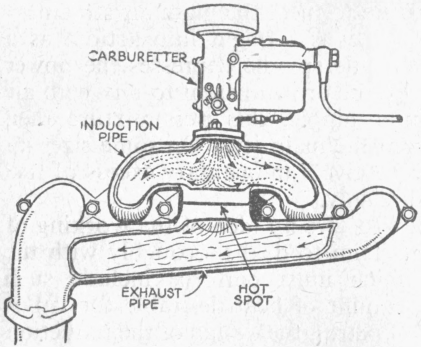
At first thought it would seem best to provide one carburettor per cylinder and simply



In the Claudel-Hobson carburettor there is a transverse passage in the throttle. A power jet comes into action at full throttle opening



Valve, port and manifold layout of a six-cylinder side-valve engine. elevation is seen on the right. Such an engine is frequently known America as an L-head arrangement. It is usual to arrange the manifolds that a hot-spot is formed immediately at the point where the petrol-a mixture enters the inlet manifold as shown below



One of the most widely used methods of obtaining an efficient "hot-spot"; the inlet and exhaust manifolds are bolted together so that the petrol-air mixture must strike against the point of junction

bolt up the instrume direct to the inlet por as is done in the cas of a single-cylinde motor-cycle engin Thus a four-cylinde engine would have fou carburettors. Actuall this is frequently don in the case of racin engines, where maxi mum efficiency is th first need.

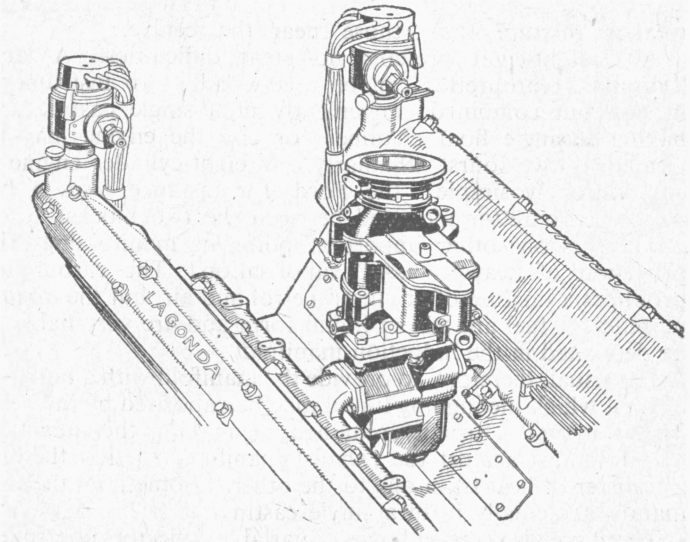
There are two mair objections to the car burettor - per - cylinde idea. The first is cost and the second is diffi- culty of adjustment. Unless each carburettor is balanced with the others poor running will ensue and it is no mean feat to synchronise four carburettors.

As against the one-per-cylinder scheme, many sports cars do have a carburettor to each two cylinders, and this gives a very satisfactory result. Two cylinders can conveniently be fed from a common inlet port if the arrangement of exhaust-inlet-inlet-exhaust for the valves is followed through the engine. Thus a four-cylinder engine is equipped with two carburettors, and a six-cylinder unit with three ; in both cases

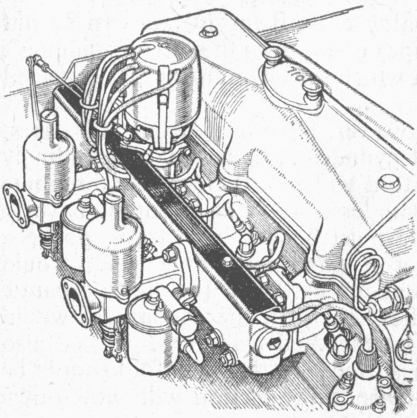
ıchronisation is reasonably easy, being in fact carried out th the aid of balance-pipes connecting the mixing chambers that part of the choke at which the incoming air has collected charge of petrol.

Most cars of to-day, however, have one carburettor, irrespective of the number of cylinders. It is not outstandingly fficult to design a manifold which will efficiently distribute e gas charge to four cylinders. Certain essentials have to : satisfied ; the manifold must be free from traps, pockets, · considerable changes of cross-sectional area which would sult in changes of gas velocity as the fuel tends to separate ıt at such points. Eddies set up in the gas stream would so interfere with its balanced distribution. It is also :sirable that the inside surface of the manifold should be asonably smooth, otherwise skin friction will slow down .e gas stream.

Then the actual port connections, the points at which the ·anches for individual cylinders enter the engine, must gister accurately and not present a sudden restriction ; the



On the V12 Lagonda a large double carburettor feeds simultaneously into the manifolds of the two cylinder blocks. In this illustration the controls are omitted for the sake of clarity



A six-cylinder "sports" engine with two horizontal carburettors, feeding 3–3, a system which is successfully used by several makers of high-performance sixes. The flanges on the carburettors are intended to be coupled up to a large air-cleaner

whole idea of an e
cient manifold bei
obviously, that it sh
provide a passa
between the carburett
and the engine th
causes as little obstru
tion and unbalanci
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Designing a si
cylinder manifold
not so easy. Diffe
ence of distanc
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remote cylinders is co
siderable, so tha
condensation tends t
occur at the ends an
the extreme en
cylinders receiv
weaker mixture than those near the centre.

A straight-eight presents no great difficulties. A larg
"double" carburettor can be used—really two instrument
in one but combined conveniently in a single casting anc
having a single float chamber—or else the engine may b
treated as two fours. Similarly a V eight-cylinder engine i
comparatively simple; the Ford, for instance, uses a big
double carburettor mounted between the two blocks.

There is one other important point in manifolding—the
provision of heat to assist vaporisation. The carburettor
produces a mixture of atomised petrol and air, but the minute
globules of fuel are still in liquid form and are very liable to
be deposited in the induction manifold.

It is usual, therefore, to provide the manifold with a hot-spot
against which the ingoing liquid may be vaporised by the heat.
This hot-spot is usually obtained by making the induction
manifold rest against the exhaust manifold, so that there is
a transfer of heat from one to the other. Sometimes the two
manifolds actually form a single casting.

There are also certain forms of variable deflectors controlled
by bi-metal coils which operate thermostatically. The deflector
(not unlike a carburettor throttle) obstructs the flow of exhaust

gas and directs it around a jacketed part of the inlet manifold while the engine is cold. As the engine warms up the heat causes the bi-metal coil to unwind, rotating the spindle of the deflector valve and so opening a free passage to the exhaust gases.

In these days it is often the custom to make connections to the manifold in order to harness its suction for one purpose or another. Screen wipers are sometimes of the vacuum type ; care is needed to make sure, occasionally, that there is no unsuspected crack in their rubber connecting tubes. This point should be watched particularly in the case of concealed wipers, where the tubing may be led behind the screen rail or up within the scuttle. Air leaks cause the mixture to be weakened and even if they are not big enough to result in serious misfiring or stoppage they will make slow and smooth idling impossible to obtain.

Other connections to the inlet manifold may be for a vacuum brake servo, or a pneumatic device to vary the ignition timing.

SUPERCHARGERS

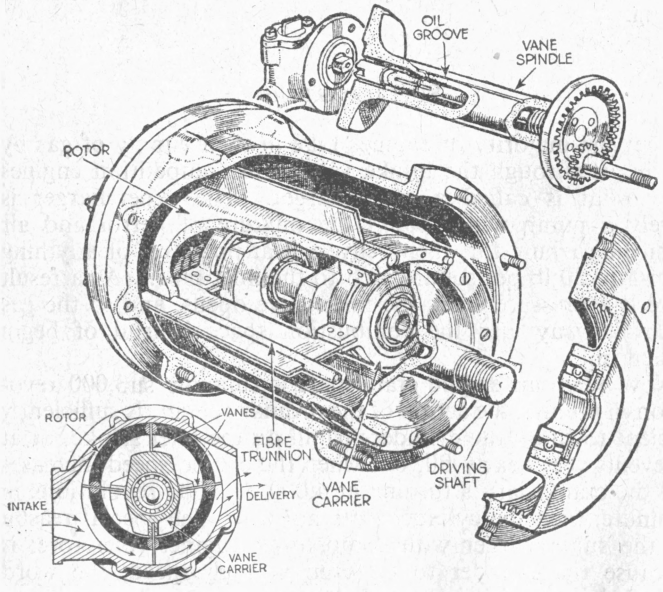
The vast majority of engines take in their supply of gas by sucking it through the intake valve, but competition engines have what is called a supercharger. The supercharger is merely a pump which sucks the mixture of petrol and air from the carburettor, then delivers it at pressures of anything from 5 to 30 lb per square inch to the inlet pipe. As a result there is a pressure when the inlet valve opens, and so the gas forces its way into the combustion space instead of begin sucked in.

Now when an engine crankshaft is running at 3,000 revolutions a minute, the action of the ordinary engine is sufficiently efficient to cause the cylinders to fill on the inlet stroke, or at all events very nearly fill, but when the engine speed increases and the crankshaft is turning at 4,000 or 5,000 revolutions in a minute, then the cylinder does not fill. The special reason for the supercharger with competition engines, therefore, is to cause the cylinder to fill even at high speed, the word " supercharging " being really erroneous.

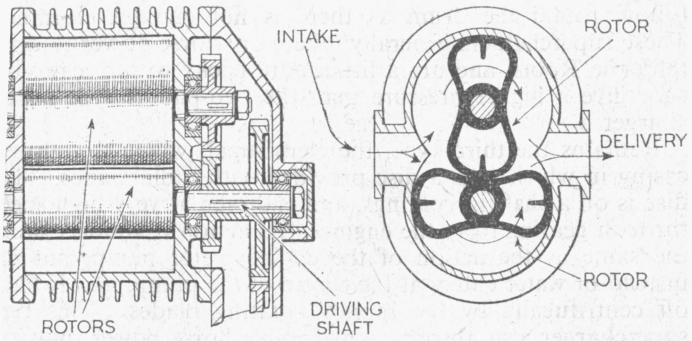
As usual, there are no advantages without attendant disadvantages, and the supercharger is not only an extra piece of

mechanism, needing lubrication, possibly troublesome, c tainly heavy, but it also takes a part of the engine horse pow to drive the pump, and the amount of horse power depen on the pressure the supercharger is designed to develop. Th is why you usually find large superchargers developing hi pressure only with competition engines, and if normal ca are provided with this extra component they have low-pressu superchargers, whose purpose is really more to improve t mixture of gas and to ensure the more even distribution this gas to the various cylinders than it is to increase t maximum power the engine can give.

It will be obvious that if the mixture of air and petrol comin from the carburettor is churned up in a rotary pump, it wi be more thoroughly mixed, just as obvious as that if the inl pipe is under pressure the gas will be more evenly distribute throughout its length. It may be mentioned in passing tha



Showing the construction of the Centric supercharger with a diagrammatic section of the single-rotor supercharger, to show the passage of the air and the action of the vanes as the rotor turns



oots supercharger: the two rotors are geared together, and their combined :tion pumps the air through the casing in the direction shown by the arrows

lthough 75 h.p. can be obtained from a normal engine rated t 12 h.p. or 1½ litres, 300 h.p. can be obtained from the same ize engine in its most efficient form and with a supercharger.

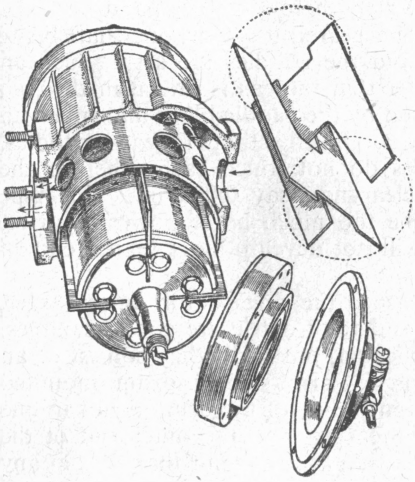
Now, as to the types of supercharger, there are three. Firstly there is the Roots, which, as the diagram shows, consists of a casing in which there are two paddles. The shafts of the two paddles are geared together, one shaft being driven from the engine, and the paddles are set at such an angle relative to each other that the gas is drawn in through one port, then carried round by the paddle blade and squeezed out of the other port by the combined action of the two paddles. The blades of the paddles do not touch each other or the casing by a very small clearance, say 0·005 in. This type supercharger does not take too much horse power to drive, is easy to lubricate, but will not develop more than a certain pressure.

Next there is what is termed the single-rotor supercharger, of which the Powerplus and the Centric are good examples. These appear more complicated, but really they consist of an outer casing, in which is a barrel-shaped drum mounted eccentrically, that is, the centre line of the drum is not in line with the centre line of the casing, and the outer rim of the drum is much nearer the casing at one point than it is at any other. Sliding in the drum are vanes and, as the small drawing of the Centric supercharger shows, the effect of these vanes is to pick up the gas from the carburettor through one port, then to force it out of the other port, because it cannot

follow round the drum as there is not enough clearance. These superchargers generally take more horse power to drive than the Roots, and are a little more tricky to lubricate, but they give a higher pressure than the two-paddle type supercharger.

Remains the third type, the centrifugal, which is simply a casing in which runs a disc provided with radial vanes. The disc is on a shaft in bearings, and is driven at very high speed through gearing from the engine. Its action is almost exactly the same as the action of the engine water pump, but gas instead of water enters at the centre of the pump, and is flung off centrifugally by the rapidly rotating blades. This type supercharger also absorbs considerable horse power, but it is at its most efficient only when it is at maximum speed, and it develops relatively little pressure at low speed.

The future may also see two-stage supercharging, which is simple enough, as it consists of one supercharger sucking in the gas and delivering it at pressure to another supercharger, which further compresses the mixture and so obtains even greater pressure.

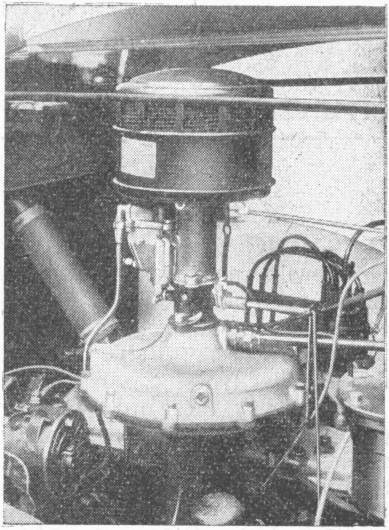


The Powerplus supercharger makes use of interlocking and sliding vanes. The rotor mounting is eccentric, but the surrounding sleeve, through which the mixture is drawn, is concentric with the casing

Out of these experiments with superchargers has come another very interesting experiment. It will have been noted that the superchargers suck gas, that is, petrol and air, from a carburettor, sometimes, as a matter of fact, from twin carburettors. That led to the idea that the petrol should be fed by small reciprocating pumps, rather like a series of squirts, to nozzles fitted in the head of the engine in place of the sparking plugs, and designed so that when the pump forces petrol

to the nozzle, or injector, the latter allows this fuel to spray into the engine inlet ports. The nozzle is automatically sealed on the explosion and exhaust strokes. Unfortunately, however, the nozzle is liable to be of considerable diameter and hard to cool.

The little battery of pumps can be adjusted very finely so that they deliver exactly the right amount of fuel to the injectors according to the speed of the engine, and also an extra amount of fuel for starting from cold. Air in the requisite quantity is then supplied either by suction or a supercharger so that air and air only passes through the inlet pipe.



An American centrifugal fan-type supercharger fitted between the downdraught carburettor and engine. Fans of this variety provide an effective boost only at fairly high speeds

It has been extremely difficult to control the minute quantities of fuel necessary to make this system satisfactory for the very small multi-cylinder engines of to-day, but once that difficulty is overcome, it is much easier to ensure that each cylinder receives its correct supply.

CHAPTER 4

Fuels and Fuel Fee

A THING that sometimes causes a certain amount c bewilderment among those who are commencing the career as motorists is the variety of different types of fu sometimes available, since it would seem at first sight that an fuel known to be suitable for one type of engine would suffic for all other types.

By the way, the word " fuel " is used advisedly in place o petrol, though petrol has come to mean any form of moto spirit. In actual fact, petrol was a special name coined fo the fuel supplied by Carless Capel and Leonard in the ver early days of motoring, and should not be applied in sobe fact to anybody else's products. But, quite apart from that the modern fuel contains many things which cannot b described as petrol if accuracy is desired.

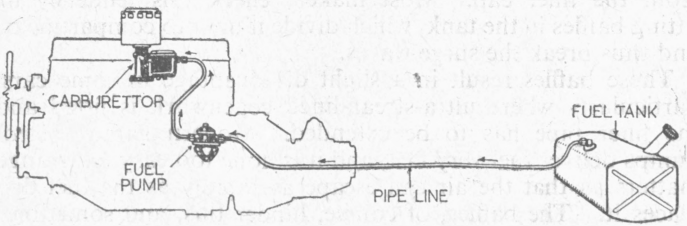
Now in the chapter describing the engine it was pointed out that the ordinary engine compresses a so-called gas made up of fuel and air, an explosion being caused subsequently by a spark between the points of a sparking plug. It was also explained that the diesel engine, otherwise described as a compression-ignition engine, has no sparking plug, the air and fuel therein being compressed to a point that automatically causes the ignition of the gas. From this it is obvious that the ordinary engine will also ignite compressed gas if the compression is higher than a certain figure, a most undesirable feature, since the moment of ignition would not be controlled accurately. Consequently the compression of engines is limited by the quality of fuel available, the designing staff desiring always to increase the power of the engine by raising the compression, the suppliers of the fuel having to keep pace with this demand. That is the reason why the various different blends of fuel appear.

If so be the engine has the medium compression of the ordinary car, a normal, or what is sometimes called "straight", fuel will suffice. For the high-performance touring car, the

orts or super sports machine, a higher compression necessi-es a different type of fuel, in order to avoid the compressed s igniting itself, or, in other words, what is called detonation pre-ignition, that is, the ignition of the compressed charge fore the spark occurs. Pre-ignition may occur when the ston has not quite reached the top of its upward stroke, nich is bad for the engine, and it may also cause a peculiar etallic noise called " pinking ", which generally occurs when e throttle is opened wide, detracting from the power of e engine and causing a great increase in the heat emanating om the engine.

To overcome this difficulty, a straight fuel, usually referred as petrol, can be mixed with other substances, with a con-derable proportion of benzole, for example, or with tetra hyl lead, or else the fuel may contain a high percentage of cohol, each mixture being known by the name used by the ipplier for the purpose of identification. Some super sports ars will even run well on benzole neat. Racing engines may equire alcohol mixtures made to a complicated and expensive ormula ; and various countries have various ideas as to the est brand of fuel to improve the performance of the cars nanufactured in their countries.

When these fuels have to be compared, the comparison is ased on their ability to stand work in an engine with a high ompression ratio without detonation, and for purpose of onvenience, the results of the tests which decide this point re set out in what is called octane values, which in theory ange from 1 to 100, a fuel with 100 octane value being better or high-performance engines than one giving a lower octane igure. Unfortunately, the method of ascertaining the octane



The high mounting of modern downdraught carburettors necessitates a fuel feed under positive pressure. The pump is often well below the level of the carburettor. Gravity systems (or even partial gravity systems) are not applicable to modern chassis layout

value is not quite the same in all countries, and moreover the process of evolution has made it possible that what was regarded originally as finality, that is to say 100 octane, is not good enough. For that reason fuels are sometimes described as 110 or more octane, which conveys the meaning well enough, but is inaccurate, since 100 is the ceiling of the octane figures.

All this is slightly complicated to the average motorist, but the thing to remember is that the fuel found suitable for an engine should be used. It would be harmful, in fact, to run a high-performance engine on straight petrol. It would be quite unnecessary to run a normal engine on alcohol.

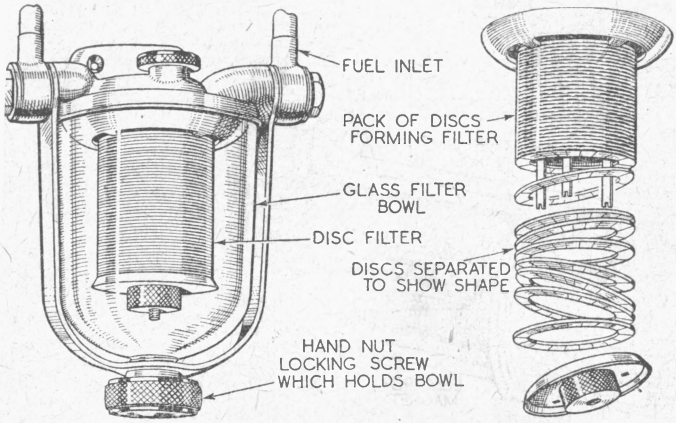
The fuel that has just been discussed has to be carried on the car, and it is accepted practice to-day to mount the petrol tank at the rear of the chassis. From this the spirit is pumped, filtered, and delivered to the carburettor.

The capacity of the petrol tank varies from four to six gallons in the case of a small machine up to more than 20 gallons on a really large car. Such a quantity of petrol represents no mean addition to the weight of the car. In older days, when the tank was always carried in the scuttle, the weight had little effect on the front part of the car. Now, with the tank at the rear of the chassis, it has been necessary for the designer to make allowance for the effect of a full load of petrol carried at the end of the frame.

For instance, something must be done to check the violent surging which will otherwise occur every time the car's direction is sharply altered, resulting in a strong tendency to " tail wag ". Then, if there is nothing to check the movement of the spirit, it will pile up at one end of the tank at every corner, and spout from the filler cap. Most makers check this tendency by fitting baffles in the tank, which divide it up into compartments and thus break the surge waves.

These baffles result in a slight disadvantage in some cars, particularly where ultra-streamlined coachwork is fitted and the filler pipe has to be extended. Modern garage petrol pumps deliver fuel very fast, and it is none too easy to arrange matters so that the air can escape as rapidly as the fuel displaces it. The baffles, of course, hinder this, and sometimes fuel will pile up in the filler and be blown back by the inner air pressure. A few cars are fitted with twin filler caps, one at either side, which does much to obviate this air-trapping.

To avoid rust, the tank is tinned inside. A petrol gauge is


FUEL INLET
PACK OF DISCS FORMING FILTER
GLASS FILTER BOWL
DISC FILTER
DISCS SEPARATED TO SHOW SHAPE
HAND NUT LOCKING SCREW WHICH HOLDS BOWL

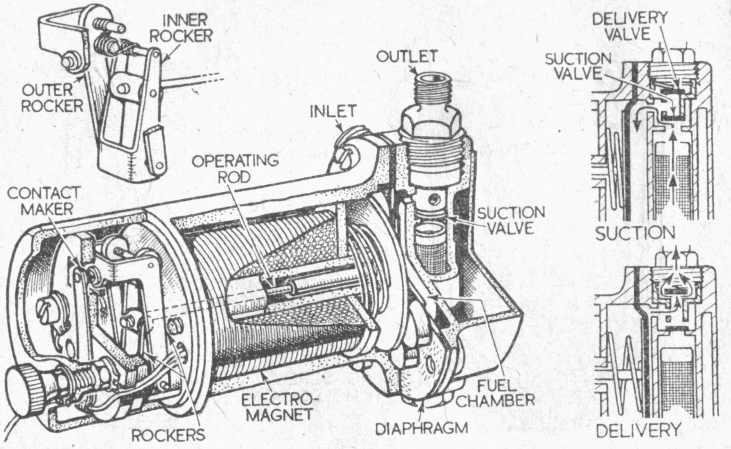
some filters a series of circular discs, packed together, replace the older type ire gauze, fuel being pumped into the bowl and finding its way between the discs to the outlet pipe, leaving the sediment behind

ıvariably fitted, generally of the electric pattern consisting of float rising and falling on an arm, varying a resistance and o translating its movements into deflections of a needle. here is a drain plug so that periodically the tank can be lrained free of sediment.

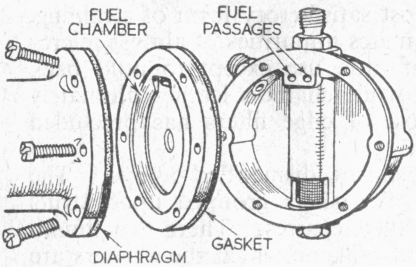
Petrol is drawn off almost, but not quite, at the lowest point n the tank ; a small gap is left for this sediment. The main ɔipe passes along the inside of the frame to the pump, which s fitted as conveniently near to the carburettor as possible. Before entering the pump the fuel may be drawn through a filter.

" Edge filtration " is a most satisfactory form of straining, since a good edge filter eliminates impurities of almost microscopic size. Gauzes are of little use except to hold back comparatively large objects, while chamois leather ultimately rots. Unfortunately the cost of edge filters has precluded their more general use.

A typical edge filter is shown dismantled above. The principle is that of a pile of washers grouped upon struts fitting very loosely through their centres. There is a thumb nut on the end of the central bolt, on which the washers are held closely together. Fine radial ridges on the washers cause them to stand apart from each other by approximately a ten-thousandth of an inch.



An S.U. electric fuel pump, sectioned to show its operation and the detail functioning of its various components



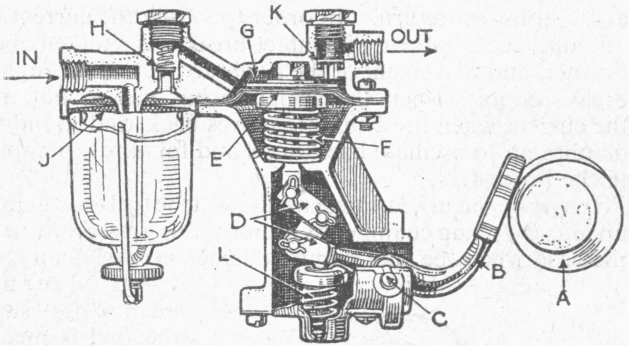
In the latest type S.U. pump the fuel chamber is a separate component, held between the body of the pump and a casing

Enclosing the whole is a stout glass bowl with a quick-release screw-tensioned clip. The petrol pump communicates with the bowl, exhausting the air. Petrol enters the bowl from the tank and can only pass on between the washers : hence the expression edge filtration. The petrol can seep uninterruptedly through the tiny slots, but water, sand, or any other intruder is trapped at the edge.

Impurities thus removed accumulate slowly in the bowl, whence they can, of course, be removed easily.

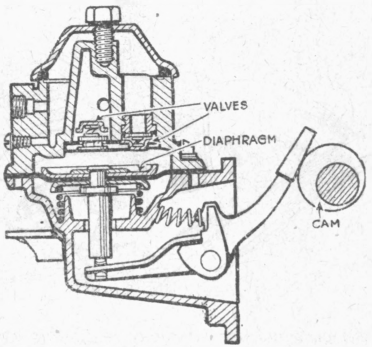
One method often used to feed fuel from the main tank to the carburettor float chamber is the electric S.U. pump, which is a very simple form of electric mechanism. Briefly, there is a chamber at the base of the pump with a connection for the pipe from the fuel tank, another connection for the pipe to the carburettor or carburettors, and a wire-gauze filter held in position by a hexagon brass cap.

Under the connection for the pipe to the carburettor are two valves, one the suction valve, which allows fuel to enter



Incorporated in this pattern of the AC pump is a glass sediment bowl which effectively retains water and heavy solid particles liable to reach the jets

the chamber from the petrol tank, but does not allow it to return, another the delivery valve, allowing the petrol to flow through to the carburettor, but not to return to the pump. One side of this chamber is sealed by a fabric diaphragm, that is, a thin disc, tightly clamped at its circumference and having a rod attached to its centre. If the rod is moved backwards and forwards, the centre of the diaphragm

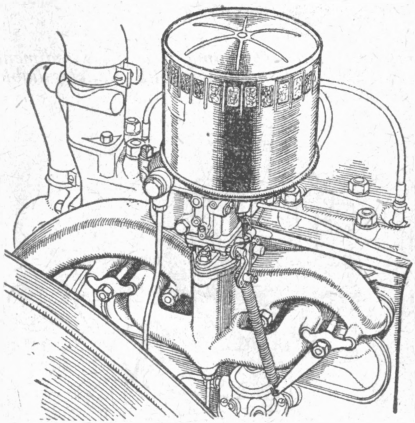


Essentially similar in system to the pump previously illustrated, this more compact design incorporates fine gauze filter screens and a sediment drain screw clearly shown at the left of the drawing

moves in the same way. Every time the centre moves outwards, fuel is sucked through the suction valve into the pump chamber. Every time the centre is moved inwards, fuel is expelled through the delivery valve.

Remains to operate the diaphragm electrically. For this purpose an electromagnet is bolted to the fuel-pumping chamber, having inside it an armature, the whole being arranged in such fashion that if current flows through the coil energising the magnet, the armature is moved, carrying with it the diaphragm. If the current is switched off, the armature and diaphragm return. In order to switch the current on and off, an ingenious form of contact-breaker is situated above the magnet, and movement of the armature, acting through levers, breaks contact when the armature has moved out, restores the current when the armature moves back, and so induces the diaphragm to oscillate backwards and forwards, pumping fuel in the process.

It may be remarked, incidentally, that the fuel is actually forced up into the pump chamber by atmospheric pressure, as is always the case when the fuel pump is higher in level than the tank.



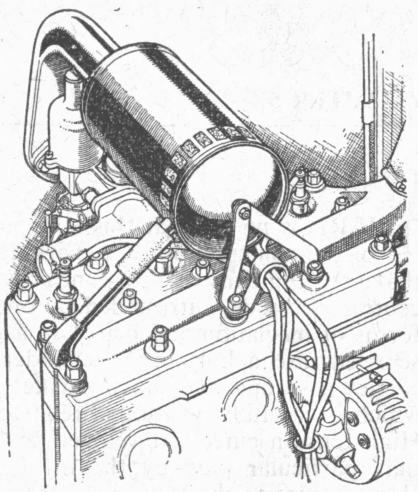
Air cleaners are now universal; this example is of the popular type in which a metal casing is filled with oil-wetted "steel wool". Maintenance merely involves a wash in petrol every 5,000 miles and re-dipping in oil. Other types of air cleaner use special felt structures which trap grit on their pile

An alternative method of supplying the fuel is mechanical instead of electrical, in which case the diaphragm is caused to oscillate by levers, themselves set in motion by a cam A (see page 85) on the camshaft, the action of the cam on lever B being just the movement that is required. The diaphragm G is held at its circumference by the body of the pump and on the pump chamber are the delivery and suction valves K and H, the first allowing fuel to flow to the carburettor but not to return, the

:ond allowing fuel to ıch the pump but t to drain back again. ther a glass or a etal bowl filter is ade up as part of the ımp, in order to trap ıy sediment, dirt or her foreign matter hich might put the ts of the carburettor ut of action.

Although the cam, cting through the ocking levers, draws ıe diaphragm down- ards, thus sucking uel from the tank, the pward movement of he diaphragm is con- rolled by a coil spring.

Air cleaners are nuch in use to-day ; he general scheme is of a device placed over he air intake designed o trap road grit and lirt, of which, partic- ılarly in dusty places, considerable quantities may be sucked nto the engine.



One great advantage of the air cleaner is the way in which it can be combined with a simple means of consuming crank case fumes. On this engine, for example, a special connection has been established, via a channel at the side of the engine, by which the oil fumes, which would otherwise tend to percolate into the body of the car, are drawn into the air cleaner and so consumed. This scheme also assists in providing lubrication for the valve gear, since the fumes are laden with oil " mist "

Various types of air cleaner have been designed, relying broadly on one of two principles : either oil-wetted wire gauze through which the air is drawn, leaving the dust on the wires, or an arrangement of fabric, the pile of which is designed to trap grit, and so on, in a similar way. Both of these types have an added advantage in that they silence the hiss of the air intake on the carburettor, which on some engines is objectionably noticeable in an otherwise silent car.

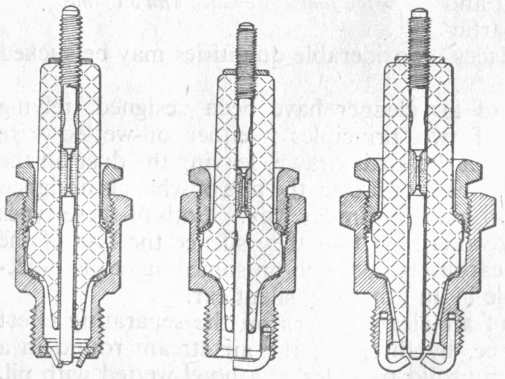
Another type of air cleaner relies on the separating effect of centrifugal force, by throwing the air stream round in a circle and collecting solid particles in a bowl wetted with oil.

CHAPTER 5

Ignitio

THERE is no need at this stage to go into minute detai of the construction of a sparking plug. It suffices to sa that the plug consists of a central wire, sometimes called th central electrode, surrounded by one or other of the variou forms of insulation and placed in a metal body which can b screwed into a hole in the cylinder head. The metal bod carries a second and much smaller wire, or outer electrod which is carefully positioned relative to the central electrod High tension current developed by the coil and switched t that particular plug by the high tension distributor passe along a wire to the central electrode, jumps the gap betwee that and the outer electrode, and thereby produces the neces sary spark. Because the h.t. current really is high tension the insulation round the central electrode has to be reall efficient.

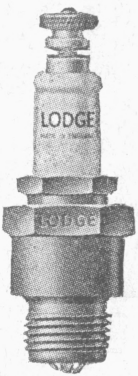
The design of all plugs has been modified considerably o late years, principally to keep the central electrode pressure tight and to dissipate the heat created at the cylinder end of the plug by the explosion of the mixture in the combustion space.

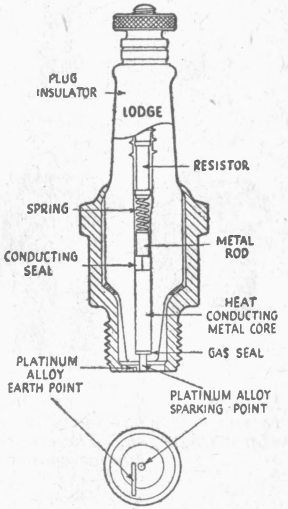


Three types of K.L.G. sparking plug, all of which have detachable bodies

The size of the plug has been reduced gradually of recent years, because the plug is a mass of metal, not

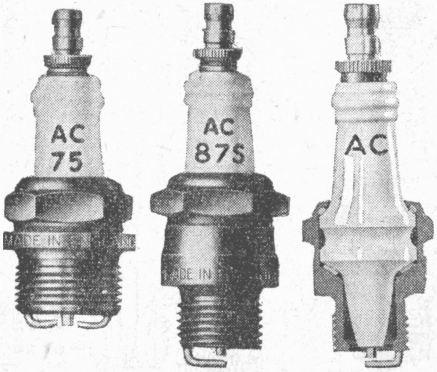
at all easy to cool, and one end of it is in the hottest part of the engine. Plugs of 10 mm diameter are now available, and also each make of plug is designed in numerous different types to suit engines which are hot and comparatively dry, engines which are hot and tend to work with a good deal of oil round the piston, engines which are cool but oily, and engines which are cool but dry. A plug suitable for the comparatively low-compression engine of the normal car would be quite unsuitable for the very high-compression engine of a sports or high-performance car, and vice versa. Also, the length of the threaded portion varies with the design of the cylinder head, and that length governs the position of the sparking plug's points, that is, the part where the spark occurs relative to the compressed gas, so that a short thread could not be used as a substitute for a plug with a long thread without reducing the efficiency of the engine, and a plug with a long thread in place of one with a short thread might project so far into the cylinder head that it might be hit by the rising piston.





A new type of Lodge plug for high-efficiency engines is an adaptation of aero plug design. The electrode points are of platinum alloy and the insulator of Sintox, a special ceramic. The central electrode incorporates an erosion resistor, that is, an electrical resistance which reduces the burning effect of the spark on the points. This plug is made in 14 mm size with long or short reach, and in 18 mm size with short reach

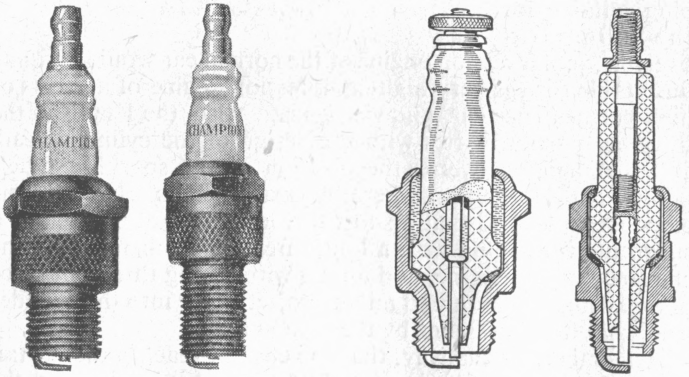
Remember, by the way, that the current reaches the central electrode via a heavily-insulated wire, but having jumped the gap and caused the spark, returns to the coil through the metal body of the plug, which is in contact with the metal of the cylinder head. The current is reversed if the + is earthed.



Examples of AC plugs of non-detachable type; an 18 mm plug with three gaps and a 14 mm plug with a single gap. The sectioned plug shows the interior construction

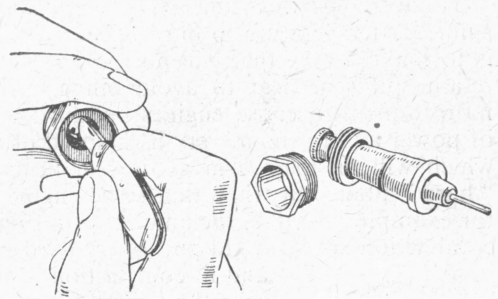
One of the most important things to remember is that an engine will not take any type of plug, quite apart from the diameter and reach. The problem is this: the end of the plug which contains the points is subject to the very hot gases created by the explosion—is, in fact, in a place where it is not over-easy to keep the metal of the plug, especially the points, cool.

Now the general diameter of the plug depends on the compression used for the engine, the type of fuel preferred, and the general running temperature, apart from the way in which

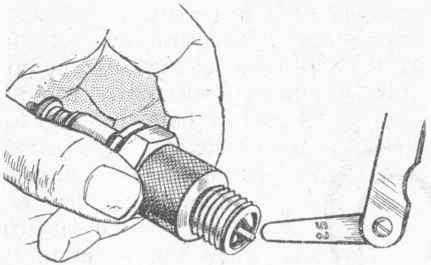


(Left): The Champion type N.8 is a long-reach non-detachable plug. (Right): The Champion L.10 is the standard 14 mm plug with a ½ in (12·5 mm) reach. A ceramic known as Sillimanite is used for the insulator

: car is driven. e plug is likely become much ɔtter, for ɜtance, if the gine is driven :quently with e throttle wide almost wide ɔen. Conse-ıently the plug ɔr a given ıgine has to be ' such design ıat it will stand



Detachable plugs need to be taken apart periodically, and the carbon carefully scraped out of the barrel with an old pen-knife. Considerable care is needed in dismantling unless a special tool is available

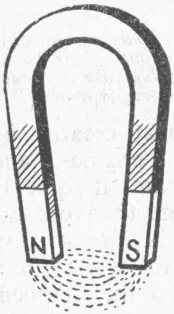


After cleaning and reassembly the gap needs to ɔe reset, by bending the outer electrode with a ɔair of round-nosed pliers. For high-compression engines a gap of 0·018 in is needed, for others 0·025 in. A plug gap gauge is seen on the right

the heat created by that engine and dissipate it quickly enough to avoid the points becoming almost white hot. Should this happen, the white-hot points may fire the compressed mixture and do so before the spark is due to occur, evidence of this being a peculiar noise resembling that given if a metal hammer were to strike a steel piston, a noise which is generally called pinking, and which not only causes loss of power but also makes the engine continue to run after the switch has been turned off, and sometimes to run backwards.

The type of point used for the plug, the metal of which the point is made and its position relative to the end of the plug has a great deal to do with the amount of heat that the plug will stand successfully. But a plug can keep too cool ; that also is bad because it stands to reason that a good deal of liquid oil works up past the piston while the engine is running and if the plug is too cool this oil is deposited on the points, where it prevents the spark from taking place and cuts out that particular cylinder.

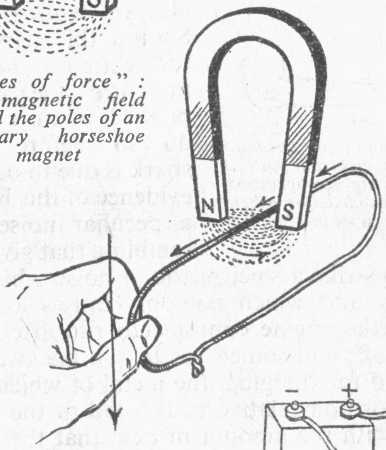
To overcome this difficulty, the plug has to be kept at a sufficient temperature to burn off oil, so you see the problem is to make a plug that will not become too hot and yet will retain sufficient heat to avoid oiling. The thing is all the more difficult because engines designed to give a great deal of power and to run at very high speed obviously need a plug which will dissipate a great deal of heat, in other words, a "hard" plug; but when that same engine has to run slowly, for example in traffic, the amount of oil reaching the cylinder combustion space would put a very hard plug out of action; and in competition engines, therefore, it is sometimes necessary to use a soft plug for slow running or warming, changing to a hard plug when the engine is required for the race or competition.



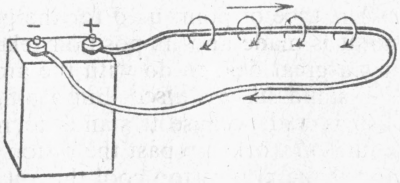
"Lines of force": the magnetic field round the poles of an ordinary horseshoe magnet

There are two methods of producing the necessary high-tension current, by means of a coil or a magneto. The coil has to be supplied with electricity from the car battery, and is useless without a supply of current, while the magneto is a self-contained instrument that generates its own electricity.

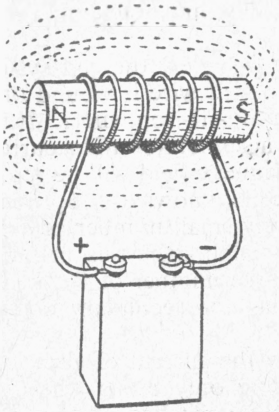
In order to understand the action of both coil and magneto it is necessary to deal briefly with magnetism. There can be few



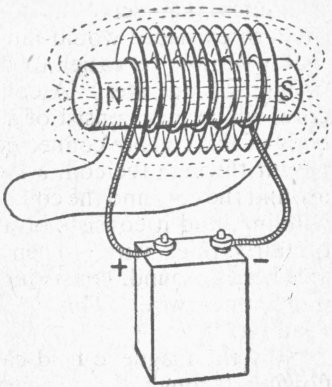
A closed loop of wire, moved through this magnetic field, cuts the lines of force and an electric current flows in the wire



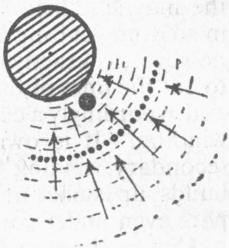
Conversely, if an electric current flows through a wire, a magnetic field is set up round it



coil of relatively few turns of irly thick wire is wound round ı iron core, and a magnetic field set up by sending a current rough the wire. This is the primary winding



A secondary winding is now superimposed, consisting of many turns of fine wire



witching off the current causes the lines of force) drop back into the iron core, in effect causing ıe secondary winding to cut across them. A urrent is induced, and owing to the large number of turns this current is at high voltage

)eople who have not, at some time, seen one of the horse-shoe nagnets beloved of every boy. They must surely remember ılso that this magnet possesses the property of attracting .o it any small piece of iron or steel brought close to it, ınd this fact alone is sufficient to prove that there is some 'orce existing around the ends, or poles, of the magnet. The sphere of influence of this force is known as the magnetic field, and the magnetic lines of force pass from the north pole to the south pole of the magnet, as indicated. (See diagram on page 92.)

It was long ago discovered that if a loop of wire is moved so that it cuts the lines of force of a magnet, an electric current is produced in the wire. It was also discovered that if an electric current is sent through a wire a magnetic field is set up around the wire. It is these facts which have made possible the development of most of the many electrical devices and

machines that serve humanity to-day and without wh modern existence would languish.

It will now be easier to describe first how the coil syst of ignition operates. A coil of insulated wire is wound or core, which may consist of a bundle of soft-iron wires. If t ends of this coil are connected to an accumulator and a curre is sent through the coil, a strong magnetic field will be set around the core and the coil. This coil is known as the prima winding, and it consists of a relatively small number of tur of fairly thick wire. Then imagine that over this first c another is wound, consisting of a large number of turns of much finer wire. This is known as the secondary coil winding.

Now the magnetic field caused by the current of electrici flowing through the primary winding only exists when tl current is flowing, and if the current is switched off the ma netic field suddenly collapses, the lines of force constitutir the magnetic field falling back, as it were, into the core, an in so doing cutting across the secondary winding. This effec however, is exactly similar to that of a wire loop being move to cut the lines of force existing between the poles of a magne and accordingly a current of electricity is set up in the secondar winding. It is owing to the large number of turns in th secondary winding that the high-tension current induced in builds up sufficient voltage to leap the gap of the sparkin plug even under compression.

That is the principle of the coil ignition system ; some o the details can now be considered, for example, the metho by which the low-tension current in the primary winding i switched off to induce the high-tension current at the correc moment. The device which does this is known as the contac breaker, and it is, in reality, an automatic switch. It consist essentially of two small contact points, tipped with the toug metal tungsten, one of which is fixed in a bracket and the othe mounted on the end of a pivoted lever, acted on by a spring so that normally the two points are kept in contact.

These two contacts are connected in the primary circuit and a small cam on a shaft driven by the engine is so place that as it rotates it comes in contact with the lever carrying th one contact point, and moves it slightly away from the fixe contact point, thus switching off the primary current. As th shaft rotates further the spring acting on the lever moves i back and makes contact again.

n the case of a
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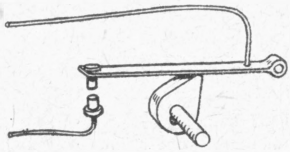
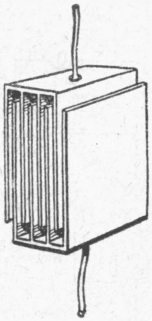
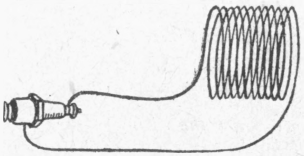


(*Above*) *Essentials of a simple contact breaker*



(*Right*) *The condenser consists theoretically of two sets of plates meshed into each other but not in contact*

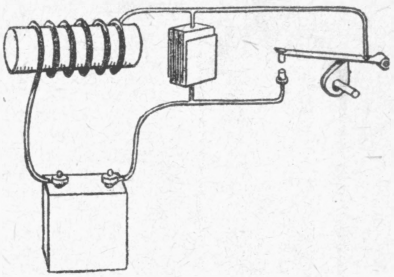


e secondary circuit, introducing the sparking plug

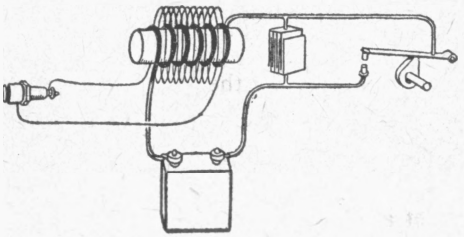
be driven from the camshaft, which, as has already been shown, is designed to run at half crankshaft speed.

The remaining component of the system (illustrated diagrammatically above) is the

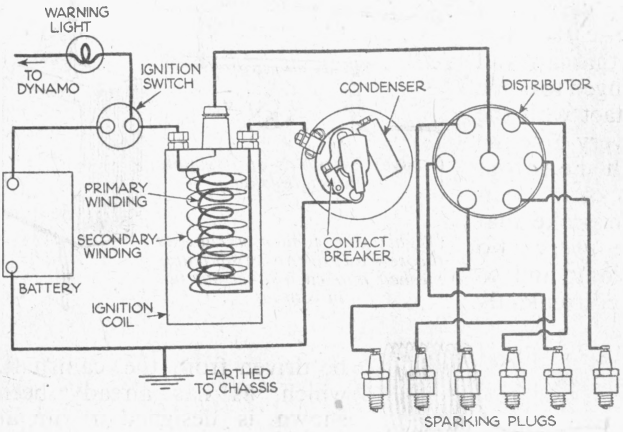
ndenser. Theoretically is has no part in the inciple of operation but practice it is most ıportant. When the ntact breaker points parate it is essential at the current flow in e primary circuit should llapse instantaneously, ıt this condition does



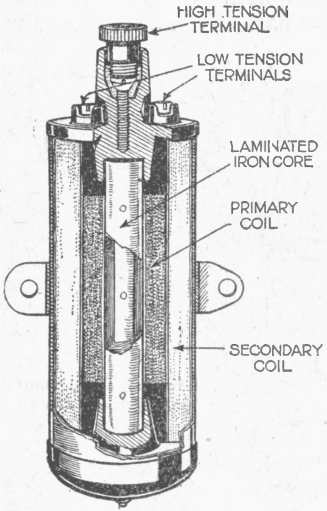
(*Above*) *The primary coil ignition circuit*



(*Left*) *Complete coil ignition circuit in diagrammatic form*



Diagrammatic layout of the ignition system to show the wiring to the various components



The structure of an ignition coil. The other end of the secondary winding is generally connected via the case to "earth". The latest practice in coil construction is to wind the primary outside the secondary

not obtain, and the current may jump the contact breaker points as they begin to open. The break in the primary, therefore, is not clean or instant, and the induced secondary current (and the spark) is weakened and mistimed.

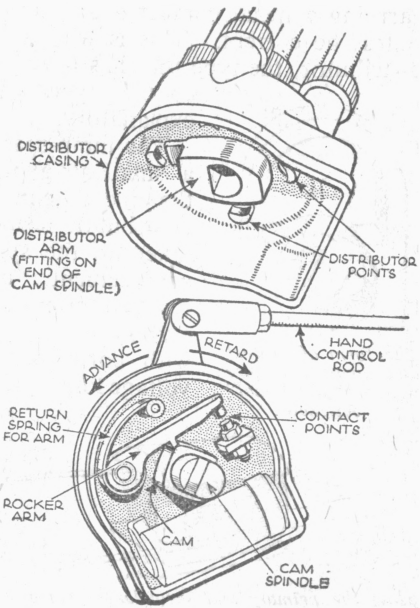
The condenser, bridging the contact breaker points, provides a reservoir into which the current can flow instead of attempting to jump the points; higher precision and intensity of the spark is thereby obtained.

Without the condenser the spark is weak and erratic in its precise firing point and heavy sparking at the contact breaker points results in their burning very badly. Sparking at the contact breaker or burned points is a sure indication of either a faulty condenser or

faulty connections thereto.

On coil-ignition equipment the condenser is usually tubular, being made of metallic foil sheets separated by waxed paper. In magnetos the condenser is generally quite inaccessibly incorporated inside the instrument and is sturdily built of thin metal plates with mica insulation.

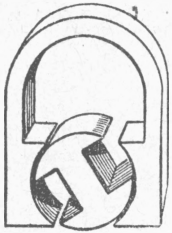
The coil-ignition system then consists of two essential parts, the primary circuit and the secondary circuit. The primary circuit consists of a winding of relatively heavy wire, the contact points and condenser, and the battery. The secondary circuit consists of the high-tension winding (of many turns of thin wire) and the sparking plug. One end of this winding is connected to the terminal on the central electrode of the sparking plug, and the other end is connected to the body of the plug. The wire, or high-tension lead, from the coil to the plug, is easily identified, but no wire will be seen connecting the secondary of the coil to the body of the plug, because the metal of the engine itself acts as a return to the coil.



A four-cylinder distributor: note that the distributor arm fits on to the shaped end of the cam spindle, but it is here shown in the position it occupies relative to the distributor casing. "Jump-spark" distribution is used in this type of apparatus. A hand control is also shown here, but automatic variation is more usual

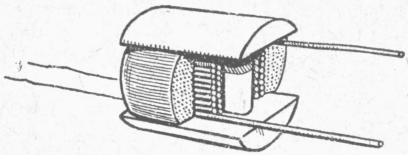
The high-tension connection from the coil enters the middle of the distributor head, and terminates in a spring-held carbon brush, circular in section and about the thickness of a diary pencil. This makes contact with the distributor rotor, which is a push fit on the cam spindle, on which it is located by a flat. The rotor is a T-shaped moulded block of insulating material

carrying a metal contact ending in the "finger" that distributes the current. This is what is known as a jump-spark distributor, the type that has to-day replaced the older wipe-contact type, the two terms being self-explanatory.



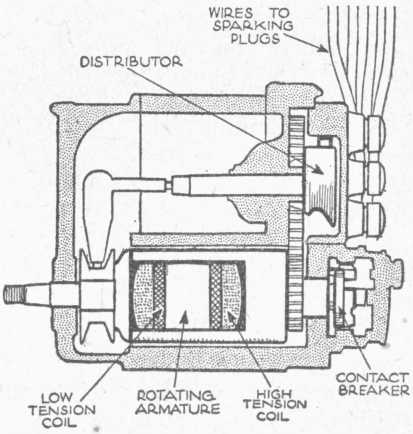
The form of magnet and armature core used in a "horizontal" magneto

The jump-spark arrangement interposes a small air-gap between the finger and the metal contacts, moulded into the distributor head, from which leads are taken to the sparking plugs. The wipe arrangement, using a carbon brush, resulted after a time in a fine trail of carbon dust forming between the contacts, with consequent leakage. This led to voltage loss, whereas with the jump system the full voltage is available right up to the instant that the spark leaps across from finger to contact.

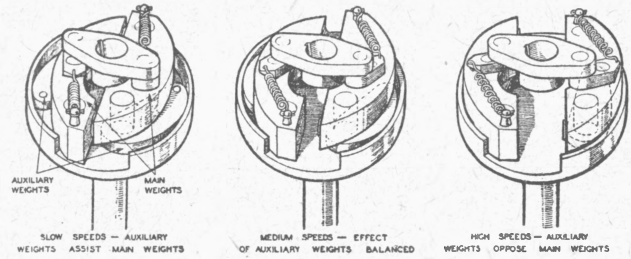


How the primary and secondary windings are installed on the armature core

If the principle of the coil ignition system has been gathered from the foregoing, it should not be difficult to gain an understanding of how the magneto works. In place of the simple horse-shoe magnet referred to, a more elaborate design is used, shaped like an inverted U, and the ends are shaped to form part of the circumference of a circle. These ends are known as pole shoes, and between them there



A magneto in section, the primary and secondary windings being here called the high and low tension coils. Note the "wipe-contact" distributor


AUXILIARY WEIGHTS
MAIN WEIGHTS
SLOW SPEEDS — AUXILIARY WEIGHTS ASSIST MAIN WEIGHTS
MEDIUM SPEEDS — EFFECT OF AUXILIARY WEIGHTS BALANCED
HIGH SPEEDS — AUXILIARY WEIGHTS OPPOSE MAIN WEIGHTS

A centrifugal timing device at slow, medium and high speed, showing how the moving weights shift the position of the coupling member. Coil springs return the weights as the speed falls

rotates the armature, which, in itself, is not unlike a coil, for it consists of a core with a primary winding and a secondary winding. The core is made of soft thin iron stampings, or laminations, bolted tightly together, and these in shape roughly resemble the letter H, the coils being wound on the central bar of the H.

The ends of the primary winding are connected to a contact breaker, and there is a condenser bridging the contact points, so that the primary circuit resembles that of the coil system. The armature is mounted on a shaft carried in ball bearings, and is rotated by the engine, and accordingly the coils of wire cut across the lines of force of the magnet, with the result that a current is set up in the primary coil. The sudden separation of the contact points by the cam on the contact breaker causes the primary current to be broken, and the magnetic field set up by it instantaneously collapses, so inducing a high-tension current in the secondary winding, just as happens in the coil system.

As the armature is rotating some form of contact that will allow movement has to be arranged for the end of the secondary winding, which is taken to the sparking plug terminal, and this is effected by a slip ring, which is merely a ring of metal carried by insulating material on the armature shaft with a carbon brush in contact with it. The other end of the secondary winding is connected to the metal shaft of the armature, and the circuit is completed through the engine to the sparking plug body.

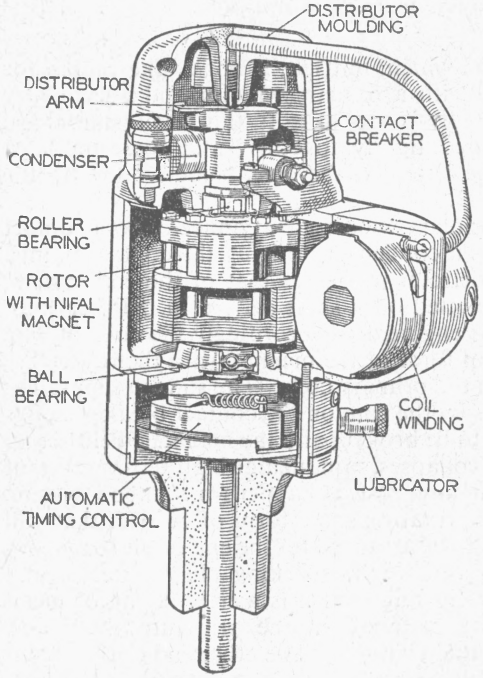
A distributor is necessary for an engine with more than two cylinders, and it is constructed in the same way as the distributor of the coil system. In the case of the magneto, however,

it is made as part of that instrument, and is driven by ge wheels from the armature shaft.

Much could be written about ignition timing. Befc making any approach to the subject here, it is necessary have a clear idea as to why variable timing is desirable.

There is little doubt that for the smoothest possible idlin or slow running, ignition should occur at, or just immediate past, the top dead centre position when the piston is about go down. It might seem that this is the right moment all engine speeds ; and so it would be were it not for the tim lag that com in, with risir engine spee since the rate c burning of th explosive mix ture is constan and irrespectiv of engine speed.

If the maxi mum expansiv effort of th burning gas i given off when the piston is ap- preciably down the power stroke, the benefit of nearly all the power exerted will be lost. The timing is then said to be "late" or " retarded ". The engine has poor power and gets very hot. This is what actually happens if the moment of ignition is not altered to suit the engine speed.

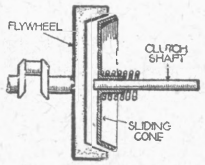


The Lucas camshaft magneto in section. This instrument is interchangeable with the distributor head of a coil ignition system. The windings are stationary while the magnet revolves ; in the case of this machine the windings are not contained in the body of the magneto, as in the Scintila Vertex, though the operating principle is similar

The faster the engine is turning, the earlier the gas must be fired, so that at all times the piston is in the right position to develop the maximum force of the explosion and turn it into useful power ; at this point the ignition is said to be fully advanced.

Should the charge be fired off so that the full explosion pressure is developed before the piston has reached the top of the compression stroke, pinking or knocking will result. When the ignition timing is thus over-advanced the knocking will be very pronounced on hills, while pinking and roughness will be especially noticeable while accelerating on the level.

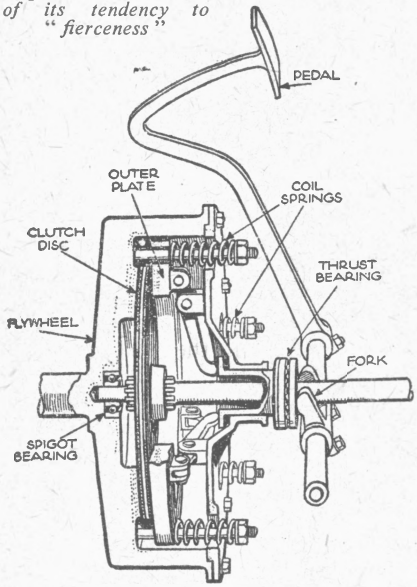
Clutch and Gear B



The parts of a simple cone clutch, a design no longer used on account of its tendency to "fierceness"

SO widely used is the petr engine in these days that mc people have some idea of how it wo and how it is made to drive the ro wheels. However, although they m have heard of the terms "clutch" a "gear box", they may have but a fai idea of what those components have to d

Obviously, it necessary to have sor device between engi and rear wheels whi will allow the one rotate without affectir the other. This devi is known as the clutch it will be easiest to cor sider first of all th cone clutch.

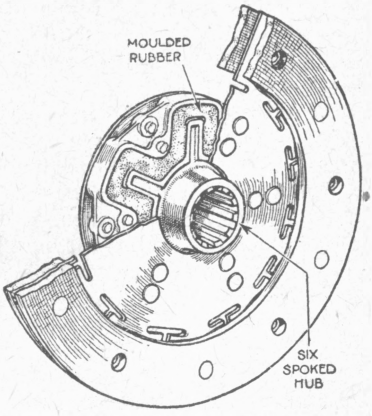


A single-plate or disc clutch. The plate is faced with friction fabric on both sides, being gripped when the clutch is engaged between the outer plate and the inner surface of the flywheel under the pressure of coil springs carried on studs parallel with the crankshaft axis

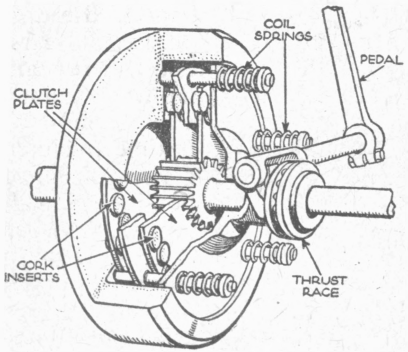
At one time the con clutch was very muc used, but it has no completely dis appeared. It could b described as a whee with a tapered o conical rim to which a lining of leather o special fabric wa riveted. The centre o the wheel is fixed on a shaft, the clutch shaft which is in line with th crankshaft, and th face of the flywheel o

engine is machined out that it presents a conical llow into which the ned wheel may fit. To ep the cone firmly in ntact with the flywheel a ge coil spring is em- oyed. Means are also ovided, by small levers nnected to the clutch dal, for separating the ne from the flywheel ainst the action of the ring.

It is now not difficult to e that when the cone is parated from the flywheel, iat is when the driver epresses the clutch pedal, ie engine may run without ffecting the road wheels, for there is a space between the ywheel and the cone. At the same time the spring is trying o force the cone into engagement with the flywheel, and if the river releases the pressure on the clutch pedal gradually, the one will make contact at increasing pressure with the flywheel and will be dragged round by it. There will be considerable slip between the flywheel and the cone at first but as the cone is forced more and more into engagement the amount of slip decreases, until finally the whole mechanism rotates as one solid mass.



A "shock absorber" effect to smooth out sudden and violent torque variations is provided by flexible clutch centres in which either rubber or springs are used



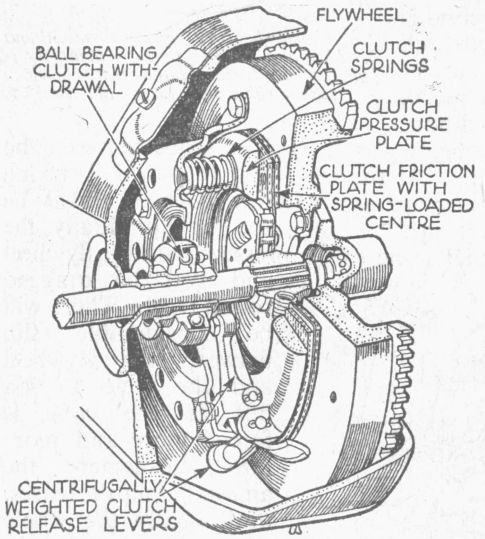
This clutch is similar in all essential respects to that described on page 102, but is a multi-plate "wet" clutch. There are two driven plates studded with cork inserts with a plain driving plate between them

The type of clutch usually favoured is known as the disc or single-plate. In this device, a surface is machined within the

flywheel, and against this is pressed the surface of a fabr lined disc able to slide to and fro on its shaft because its b is splined and the splines fit other splines on the shaft. effect, two discs are pressed against each other with sufficie force to transmit the drive, but can be released from ea other, thus freeing the engine from the gears, when the driv presses forward a pedal.

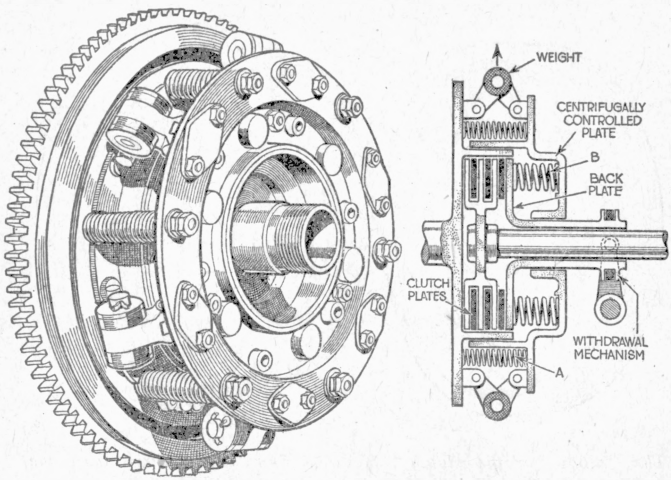
But it is as well to describe the clutch in greater detail.

To allow the clutch disc to move freely out of engagemer it is not rigidly fixed to the clutch shaft but is carried on ridg or splines which fit in grooves in the central hole of the dis The disc can thus move along the shaft, but rotates with The clutch is enclosed, whether it runs in oil or not, ar practice to-day is in favour of the dry-plate clutch with friction fabr lining, althoug some older ca are still fitte with the oil-bat version makin use of cor inserts.



The torque of a powerful engine requires heavy pressure between the clutch plates if slip is not to occur, particularly when accelerating. Since it is impracticable to increase the spring strength beyond a certain point at which operating the pedal becomes heavy, centrifugal weights are often used to give an increase in the plate pressure proportionate to the speed at which the assembly is spinning. This scheme is so successful that the operation of the pedal can be made as light as the accelerator without slip developing

Develo pmen and improve ment of the dry plate clutch hav continued over a period of years and there ar now many varieties o flexible clutch discs, spring o "cushion" clutch centres, and the like, which ensure smooth take-up of the drive and free-dom from "judder" when starting from rest. Nevertheless, on



In the Newton clutch another layout of the scheme using centrifugal weights relieves the driver of all responsibility.

many sports and racing cars the solid-centre clutch is retained, as it is quick acting.

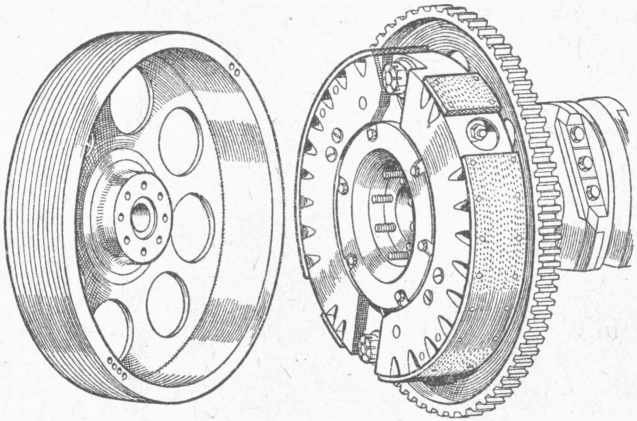
In recent years the popularity of cars among the non-mechanical has led designers to produce various types of automatic clutches.

One of the most obvious methods of arranging for automatic clutch control is by centrifugal action which increases the pressure between the clutch plates in proportion to their rotational speed. Pivoted weights tend to move outwards under the action of centrifugal force and are thus made to take the place of or to augment the pressure of the clutch springs.

The Newton centrifugal clutch is a good example and it relieves the driver of all responsibility in the matter of physical control, for it engages gently, yet firmly and decisively, as the engine speed rises above 600 r.p.m., similarly disengaging as it falls below that speed.

The " traffic clutch " used on Talbot cars some years ago was similar in principle, but the pivoted weights were in the form of shoes which pressed upon a surrounding drum.

Certain modern cars have clutches in which the springs are



The Talbot "traffic clutch" of some years ago differed from the Newton apparatus in that shoes were used much as in a brake-drum, instead of plates

reduced in number and bob weights supply centrifugal ass tance. This gives a light clutch pedal action and smoc engagement, but the grip increases with engine speed.

The Bendix control was another example of automa engagement or disengagement of the drive. In this case t clutch pedal is connected, via a linkage, to a piston within cylinder communicating with the induction manifold ar whenever the throttle is closed the rotation of the engi induces a considerable depression therein, so that atmospher pressure drives the piston along the cylinder and the clutch thus automatically disengaged. The driver's responsibiliti in this case were limited to nothing more than mere movemer of the gear lever.

A control is provided to isolate the system from the manifol so that the clutch may be operated normally by the pedal.

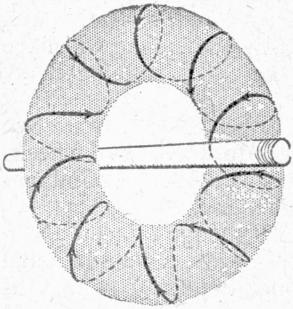
As a variation of the usual clutch, an hydraulic coupling ca be used. This type was adopted under the name of the "flui flywheel" by the Daimler Motor Company in 1930, havin been developed by a British engineer, Harold Sinclair o Hydraulic Coupling Patents, Ltd., out of an invention by Dr Fottinger, a German who in 1905 adapted this form of couplin to the transmission gear of ships' engines.

While the hydraulic coupling was widely adopted fo

industrial purposes and was applied to Daimler and A.E.C. buses, it figured only on Daimler and Lanchester cars until in 1939 American engineers began to appreciate its peculiar properties and Chrysler adopted it, to be followed by others.

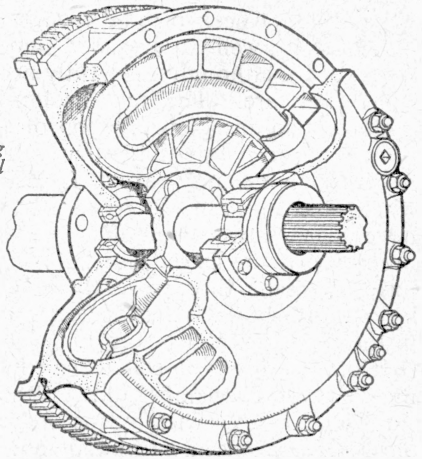
The drive is transmitted by means of oil projected from a driving to a driven member. The diagram below shows the path followed by the fluid, and the actual fluid flywheel is also shown in section. The driving member, which also constitutes the flywheel (hence the name of the device) is bolted to the end of the crankshaft; formed in it is an annular ring of semi-circular cross-section, which is divided up into a series of cells by radial webs. The driven member, which is bolted direct to the primary shaft of the gear box, has a similar annular ring divided into radial pockets.

The body of the fluid coupling is about three parts filled with oil. As the flywheel revolves, the oil is flung by centrifugal force from the cells of the driving member against the webs of the cells of the driven member.



A definition of the working principle of the fluid flywheel depicted diagrammatically

The amount of drive which will be transmitted to the driving member depends upon the force with which the oil is thrown against the webs of the driven member. Since this oil is thrown out by centrifugal force the slip at low engine



Fluid flywheel partly sectioned. In recent designs the annular guide around the centre of the vanes has been omitted, giving what is called an open circuit. The effect is materially to reduce the slip at normal speeds

revs. is considerable, but it rapidly decreases until at speeds of over 1,000 r.p.m. it practically disappears.

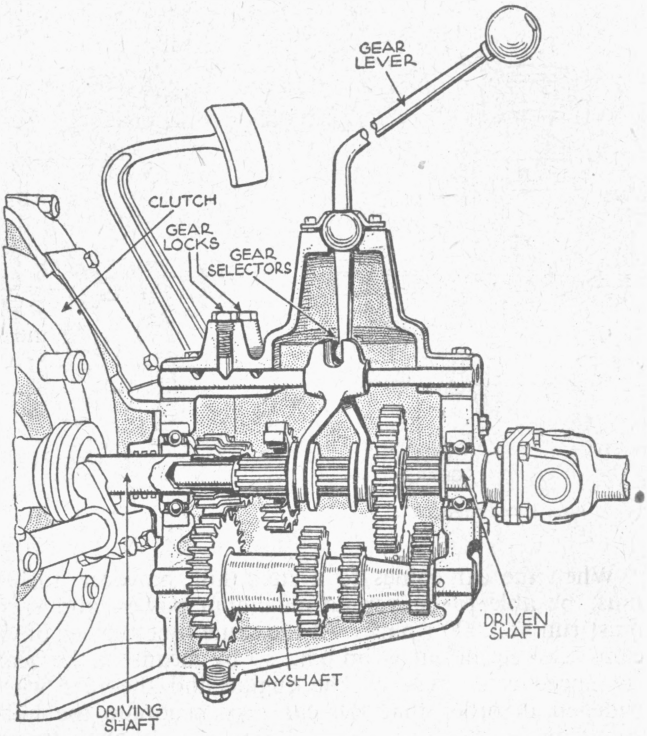
If the resistance offered by the transmission (that is to say, the contact of the tyres with the road) is sufficiently great to overcome the driving action of the oil flowing from the cells of the driven member, the car will not move forward at all even though a gear is engaged. However, as soon as the engine is speeded up, the kinetic energy imparted to the oil by the driving member is transferred to the driven member in sufficient volume to enable the car to gather way. It is therefore possible for the car to be brought to rest with a gear engaged and driven away merely by accelerating the engine.

The next item to consider is the gear box, by means of which, as has been explained, the engine is enabled to run at a suitable rate of revolutions to meet the requirements of varying conditions. These include ascending hills and starting away from rest, when obviously the engine will have to develop more power than when the car is running easily on a level road.

The gear box is a rigid metal case, or box, in which are two parallel steel shafts carrying a number of toothed metal wheels, or gear wheels. By means of the gear lever different combinations of gear wheels may be brought into use.

It may be well to consider some elementary facts about gear wheels, although it is hardly necessary to explain in detail what they are. The relationship between gear wheels is important in any consideration of function where rotation is transferred from one to another. It is important to know, for example, that if one gear wheel has 20 teeth and another with which it is in mesh has 40 teeth, then the smaller wheel will have to make two revolutions for one revolution of the larger. Similarly, if the larger wheel has 60 teeth the smaller would have to make three revolutions for one revolution of the larger. In the first case the gear ratio is said to be 2 to 1, and in the second case it is 3 to 1.

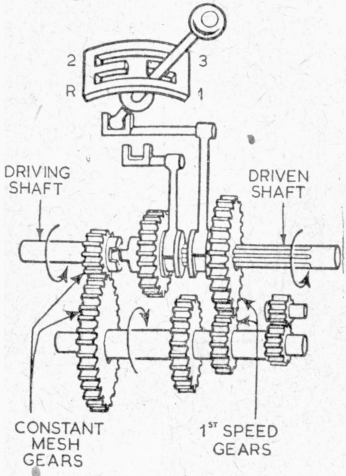
It has already been stated that the faster an engine runs the more power it develops, and it is this fact which makes necessary a gear box, whereby the gear ratio between the engine and the rear wheels can be altered as circumstances require. If a car were built with only one speed, that is one gear ratio, the engine would have to be unduly large and powerful ; otherwise, although it was sufficiently fast on the level, it would not be able to climb hills. It is harder to walk or run



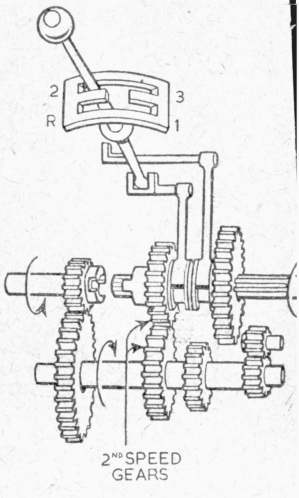
Cutaway view of a three-speed and reverse gear box of the simplest type. All the gears have straight teeth and there is no kind of "easy-change" mechanism. Such gear boxes were widely used for many years

p a hill than it is on the level, the reason being that on hills ve have to lift our weight. In the same way the engine has o lift the weight of the car on a hill.

Accordingly, for ordinary running the gear ratio between he engine and rear wheels is so chosen that on the level at an rdinary touring pace the engine is running at a moderately ow speed. For example, in a car capable of doing 60 m.p.h. when the engine is doing 3,000 revolutions per minute (usually written as r.p.m.), the engine will only be running at 1,000 .p.m. at 20 m.p.h., at which speed it should run very smoothly nd quietly as it is not working hard.



First speed engaged

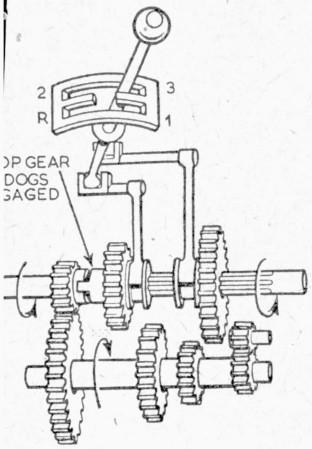


Second speed

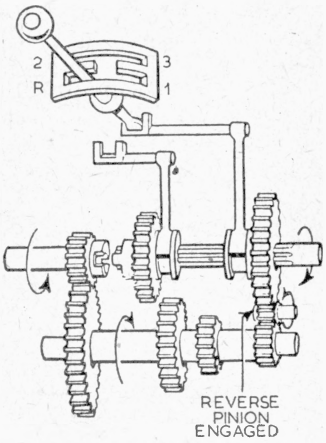
When the car comes to a steep hill, however, the engine must be able to deliver its maximum power, and therefore must run at 3,000 r.p.m. At the same time the car obviously cannot go up hill at 60 m.p.h., so by means of the gear box the speed ratio between the engine and the rear wheels is widened in order that the car may negotiate the hill at a comfortable speed, say 15 to 20 m.p.h., although the engine is turning at 3,000 r.p.m.

Most cars have four speeds, that is four gear ratios, but there have been, and still are, many three-speed gear boxes, and as the principle of operation is the same it will be easier to deal with this type. To the clutch shaft there is attached a shaft which runs back into the gear box and has, formed on the end of it, a gear wheel. In the end of this shaft, known as the driving shaft, there is a hole which forms a bearing for the end of another shaft, known as the driven shaft, or tail shaft, which projects out through the back of the gear box.

The driving and driven shafts are, therefore, in line, but, owing to the spigot bearing of the driven shaft in the end of the driving shaft, the one can rotate without causing rotation of the other.



Third or top : " dogs " are used



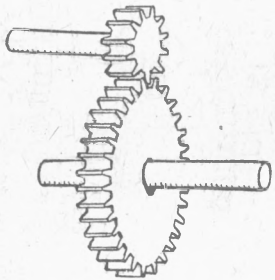
The separate reverse train of gears

Beneath this combined shaft there is another shaft, known as the layshaft, and on this there are set three gear wheels, the largest of which is always in mesh with the gear wheel on the driving shaft. Accordingly, these two gear wheels are known as the constant-mesh gears. It should, perhaps, be explained that when two gear wheels are in mesh the smaller is referred to as a pinion, and as the wheel on the driving shaft is the smaller it is known as the constant-mesh pinion, while its companion on the layshaft is known as the constant-mesh gear.

There are also two gear wheels on the driven shaft, and this shaft has ridges, or splines, formed on it. Grooves in the central holes of its two gear wheels coincide with the splines so that they can be made to slide along the shaft but are forced to rotate with it. These slidable wheels have collars formed on their sides. These, being engaged by sliding forks which are operated by the gear lever, allow the driver to move the gears along the shaft as necessary.

Projections are also formed on the side of the gear wheel next to the constant-mesh pinion and on the side of the constant-mesh pinion itself, these projections forming what is known as a dog clutch.

When the gear lever is in the neutral position the t sliding gears are so placed on the driven shaft that they not in mesh with any of the other gear wheels, and the p jections on the side of the one sliding wheel and on the c stant-mesh pinion are also out of engagement. According when the driving shaft, and with it the constant-mesh pini rotate, they cause the constant-mesh gear, and therefore t layshaft and layshaft gears, to rotate also, but the driven sh will remain stationary.



Of two gear wheels, the smaller is generally called a "pinion"

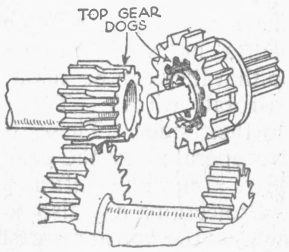
In starting from rest the low gear is necessary in order that t car may be made to move smoothly and gradually witho stopping the engine. Accordingl the driver depresses the clut pedal, and as the clutch is dise gaged the driving shaft comes rest, and so the constant-me gears come to rest also. The ge lever is then moved into the fir gear position, causing the large wheel on the driven shaft to slid into mesh with the smalle forward-speed layshaft pinion.

As the clutch is engaged power is transmitted from th constant-mesh pinion to the constant-mesh gear, and throug the layshaft and the first speed driving pinion on it to th larger wheel, or first speed driven gear, on the driven shaft.

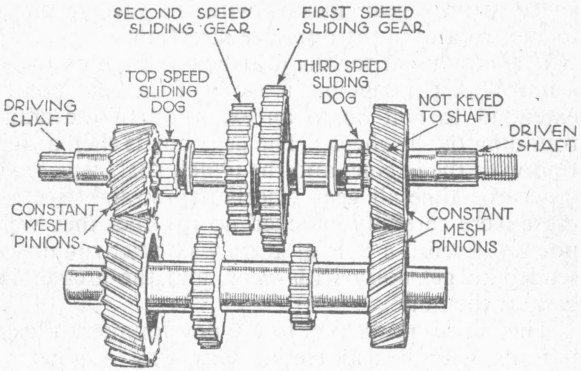
The constant-mesh pinion being smaller than the constant mesh gear, there is a certain gear reduction, which is magnifie by another reduction, as the first speed driving gear is smalle than the first speed driven gear.

As the car gathers speed it becomes desirable to change to a higher gear in order to let the engine run more comfortably and more economically at a considerably lower rate of revolution, so second gear is engaged.

Accordingly, the driver pushes forward the clutch pedal and moves the gear lever, the first part of the movement sliding



An arrangement of top gear dogs drawn apart to show how meshing takes place



A "silent-third" gear box, with two sets of helical constant-mesh pinions, such as was widely used before synchromesh became general

the first speed driven gear out of engagement with the first speed driving pinion, and the second part of the movement sliding the other gear wheel on the driven shaft, the second speed driven gear, into engagement with the second speed driving gear on the layshaft.

As the clutch is engaged again power is transmitted through the constant-mesh gears and from the second speed driving gear to the second speed driven gear. As the two latter gears are of approximately the same size, the gear reduction is not so great as in the case of first speed.

Finally, it is desired to change into top gear, and the gear lever is moved again, sliding the second speed driven gear out of engagement with the second speed driving gear and towards the constant-mesh pinion, so that the two sets of projections, forming the dog clutch, on the second speed driven gear and the constant-mesh pinion come together.

Power is then transmitted direct from the driving shaft to the driven shaft through the dog clutch, and hence the top gear is sometimes known as the direct drive.

In order to obtain a reverse gear it is necessary to make the driven shaft revolve in the opposite direction, and this is done by means of another gear, on a small shaft of its own, in mesh with a fourth gear on the layshaft (as shown in the diagrams on page 111) or with the first speed driving gear. When the gear lever is moved into the reverse position the first

speed driven gear meshes with the reverse pinion, and t former rotates in the opposite direction.

It is now usual for the gear box and clutch to be formed a unit with the engine, the front of the gear box casing bei extended to bolt on to an extension of the crank case su rounding the flywheel. The gear box is then a rigid constru tion with the engine, and the clutch shaft is very short.

At one time all gear wheels had straight teeth, but unle these were carefully matched up together they were apt to t noisy. Even if a pair of gears was quiet running at first the tended to get noisy with wear, and the greater the wear th greater the noise.

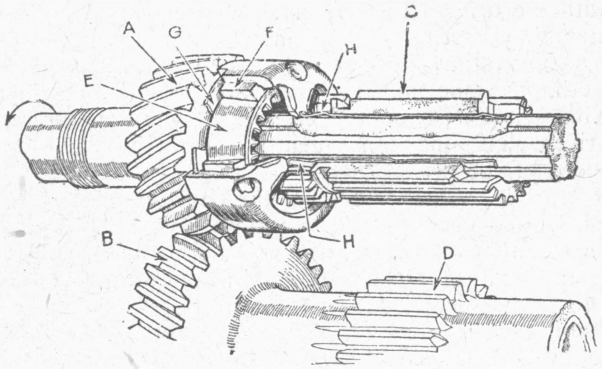
This noise trouble led to the development of gear wheels c pinions with helical teeth, presenting a greater surface c engagement and allowing the gears to fit closely and smoothl into one another, with an enormous reduction in noise This use of helical teeth, however, makes it impracticable t slide the pinions in and out of mesh in order to change gear so that for the engagement of helical gears the use of the do clutch is necessary. The most modern types of gear bo have all their gears (except reverse) of the constant-mesh pattern, engagement being effected by sliding dogs as with top gear.

With the achievement of the silent gear box, there followed an enormously rapid development of mechanisms to facilitate gear changing. The popularity of motor cars begot a class of driver who was sufficiently lacking in mechanical " feeling " as to be unskilful (and often untrainable) in the art of gear changing by the method known as double declutching.

The success of the original Model T Ford was unquestionably largely due to the foolproof change of its simple epicyclic gear. This epicyclic principle is explained later ; it inherently favours easy manipulation. Epicyclic gearing, however, cannot be fittingly considered alongside the normal gear box, in which gear wheels have to be selectively locked to their shafts.

The basis of all gear-changing problems is the same : that of bringing into mesh two gear wheels—after all, a dog clutch is only a gear wheel with very coarse teeth— turning at different speeds. By double declutching the driver increases the speed of the slower wheel until it matches that of the faster, and the two can slip noiselessly into mesh.

The same ultimate result would be produced if the faster



Synchromesh : top gear engagement

gear were slowed down to the speed of the slower. Now if by some means the slower gear, as it is pushed along the shaft towards the faster, could be made to apply a brake to the faster one, the problem would be solved—this is the principle of syncromesh, one of the most widely adopted of modern automobile innovations, first developed in America by General Motors. As the slow gear is pushed towards the faster, before their teeth can meet and grate together, a projection on the side of the slow gear meets and presses noiselessly against a recess on the fast gear. Thus the two gears are quickly brought to the same speed, and so can be meshed into each other.

An early synchromesh mechanism illustrated above can be considered. There is, as usual, the driving shaft, the driven shaft, and the layshaft, the driven shaft fitting into a spigot bearing in the driving shaft as usual. The constant-mesh pinions A and B are mounted one on the driving shaft and the other on the layshaft. In the middle of the driven shaft, which is splined, is a sleeve (C) internally splined to fit the splines of the driven shaft, and also externally splined ; on these external splines is mounted the first speed gear wheel (not shown), which is moved along the external splines by its selector in the usual manner to mesh with the first speed pinion (D) on the layshaft. First speed, therefore, is engaged normally, by means of a sliding pinion.

To describe the synchromesh mechanism the engagement of top gear may be taken. The driving shaft has to be engaged

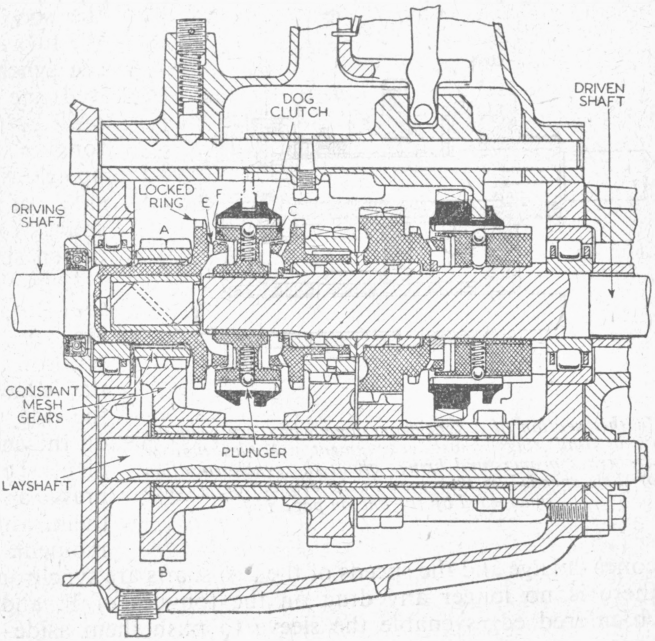
with the driven shaft so that both rotate at the same spee giving a direct drive. A cone (E) is machined at the side the constant mesh pinion (A). This cone has a ring of intern teeth. A cone ring (F) fitting over the cone (E) has tongu which fit loosely in the grooves between the splines of th driven shaft and consequently it must always rotate at th speed of the driven shaft.

Thus if the cone (E) and the coned ring (F) are brough hard into engagement driving and driven shafts will be con nected, and will rotate at the same speed, and it will be possibl to engage a positive drive by means of dog teeth between thes two shafts silently and without effort. When top gear is no being used, the coned ring (F) is kept free of its cone (E) retained by a special distance washer (G).

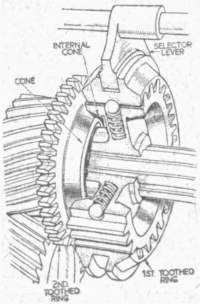
In imagination move the gear lever into the top gear position so that the selector slides the sleeve (C) to the left. The selector fits in an annular groove cut out of the circumference of the sleeve ; and the end of the sleeve (*i.e.*, the part carrying the teeth which will engage with the internal teeth of E) has slots cut as clearances to allow it to slide past the tongues of the coned ring (F). The whole length of the teeth at the corner of each slot is chamfered, for a purpose which will be described later.

The sleeve passes over a number of blade springs (H) which fit beneath it between the splines of the driven shaft. The springs possess a " kink " at each end, so that the action of the sleeve is to push the end of the blades against the tongues of the coned ring (F), which, it will be remembered, also fit between the splines of the driven shaft ; the pressure exerted pushes the coned ring (F) towards its cone (E), and the contact between the two begins to synchronise the speeds of the driving and the driven shaft. Eventually, as the selector moves the sleeve farther still to the left, the corners of the slots in the end of the sleeve, which are chamfered, butt up against similar chamfered edges on the tongues of the coned ring (F), thus preventing the sleeve from moving any farther to the left until the speeds are synchronised.

Until this happens there has been a certain amount of slip between the cone and its ring, the friction tending to synchronise the speeds of the two shafts, as has been explained. It has been mentioned that the tongues of (E) are a loose fit in the grooves between the splines of the driven shaft, and as long as slip is taking place between the cones (in other words until



Section of a modern synchromesh mechanism, showing the spring-loaded ball by means of which the internal cone is made to press against the cone, after which the ball is depressed, allowing the first toothed ring to slide further to the left and mesh with the second toothed ring



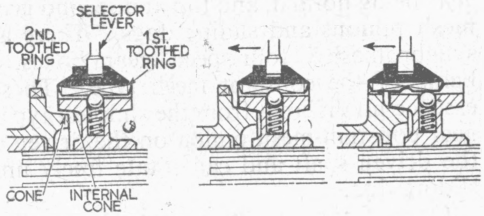
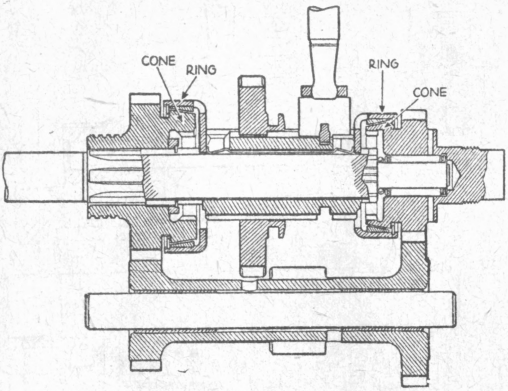


Diagram showing the exact movements of the parts of a modern synchromesh mechanism

(Left) : This is what the synchromesh mechanism looks like



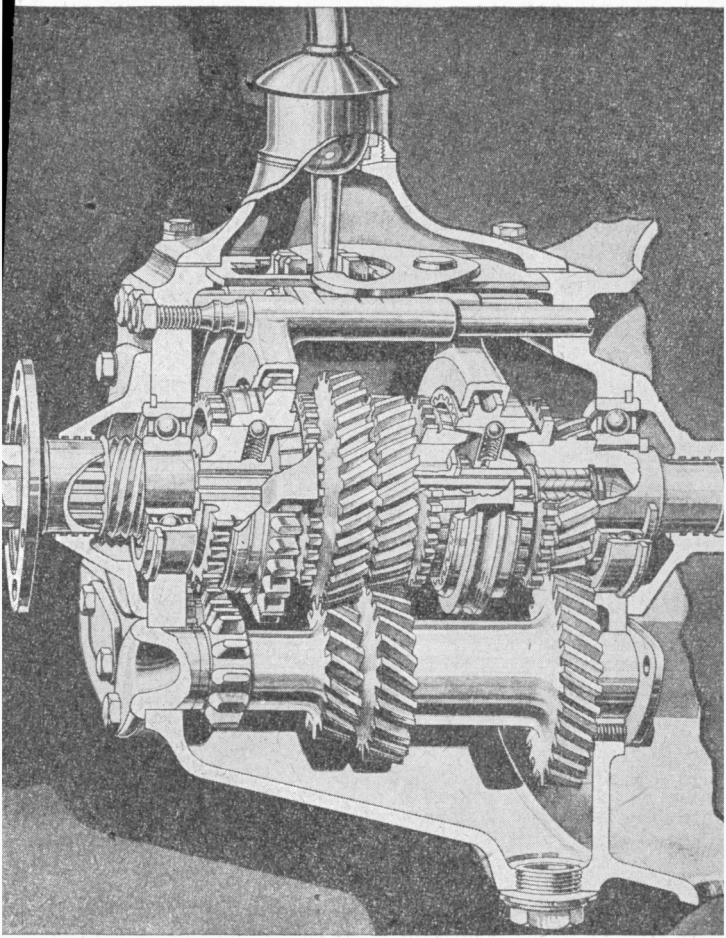
In this section of a synchromesh gear box are seen the cones and rings whose engagement precedes that of the gears proper, and brings about the synchronisation of their speeds—as they were in the original design now superseded by the one on page 117

the speeds of the two shafts are synchronised) the drag on E keeps its tongues hard up against one side of the splines on the driven shaft.

It is when the tongues are in this position that the edges of the dog teeth on the end of the sleeve press against them, but the moment the cones engage and the speeds of the two shafts are synchronised there is no longer any drag on the tongues of F, and the chamfered edges enable the sleeve to push them aside—the tongues passing into the slots cut for them—and the dog teeth get past into mesh with the internal teeth cut on the cone (E), locking the two shafts together and thus engaging " top gear ".

In the drawings a three-speed box is illustrated, bottom gear being normal, and top and second gears utilising constant-mesh pinions and sliding dogs. There are now several " all synchromesh " four-speed gear boxes, all forward speeds being of the constant mesh type. These gear boxes are in essence no different from the simplest type save that the second gear constant-mesh pinion on the driven shaft is not keyed to the driven shaft and can rotate freely until locked to it by a sliding dog.

One of the two pinions to be meshed has, on the side presented towards the other pinion, a conical projection very much like the driven member of a cone clutch. This projection, before the gear teeth can come into contact, meets and presses into a recess in the opposing pinion, shaped to fit it ; the two pinions are thus held in contact by the pressure of the driver's



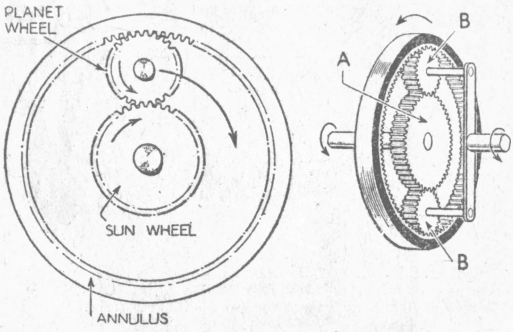
Typical of modern practice : a four-speed Austin gear box with the synchromesh principle applied to second, third and top gears. The straight teeth (lower left) are those of the first and reverse gear trains, which are " plain " gears

hand on the gear lever until their speeds have synchronised ; then they slip into gear.

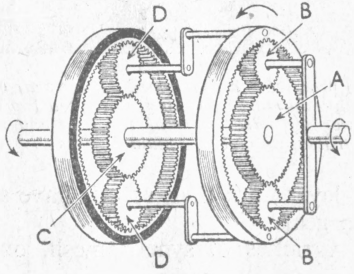
There are two varieties of synchromesh, one lighter and

slightly simpler than the other. On the more robust patte it is impossible to clash the gears, but with the lighter and l expensive pattern, over pressure on the gear lever results over-riding the synchronisation and bringing the gear tee together too soon, with, of course, audible results f all to hear.

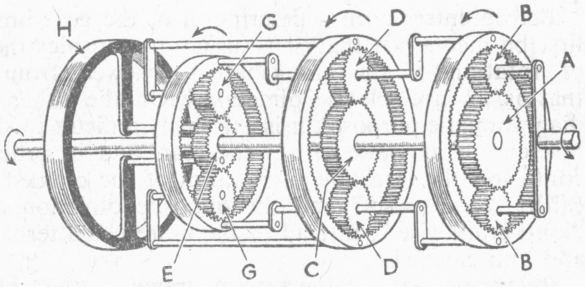
Epicyclic gears were used a great deal in the early days motoring and then for many years they disappeared. A ne development which exploited a hitherto unexplored possibili of the epicyclic system appeared comparatively recently as t " self-changing " or " pre-selector " gear box. The Wilso gear box, to give it its true name, uses epicyclic or " planetary gears. There may be a normal plate clutch combined wit the gear but, in theory, at any rate, it is not actually necessary for in the construction of the gears themselves friction device are incorpor ated enablin the drive t be taken u smoothly. Th " gear lever," too, no longe actually engages the required gears, but when it is moved into any of the different slots merely " pre-selects " a ratio, which is brought into operation when desired by depressing and releasing a pedal similar to the normal clutch pedal. The self-changing box is particularly



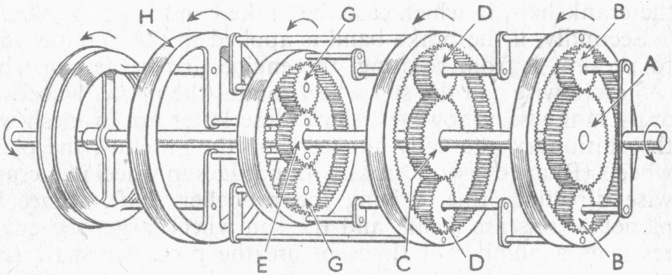
(Left) The principle of the epicyclic gear. When the annulus is fixed the planet carrier travels around the sun wheel in the same direction but at a lower speed



(Right) By coupling up a similar gear train to the first speed arrangement, the " reduction is reduced ", and second gear results



Third gear is obtained in a similar way, but a separate brake drum is used



The addition of a cone clutch locks the entire mechanism to give a direct drive for top gear

uitable for use with a fluid flywheel or with an automatic centrifugal clutch, neither of which calls for the use of a clutch pedal.

The principle of planetary or epicyclic gears is illustrated. There is a central sun wheel, round which run small planet wheels (exactly as in the solar system the planets rotate round the sun) ; the planet wheels also mesh with an internally toothed annulus. This toothed ring itself may or may not rotate.

Looking at the next illustration, the sun wheel A is coupled direct to the crankshaft of the engine ; the spindles on which the planet wheels B revolve are connected by an arm to the propeller shaft. The annulus is equipped with an external band, which is shown for the sake of clearness in the diagram by means of a heavy black line.

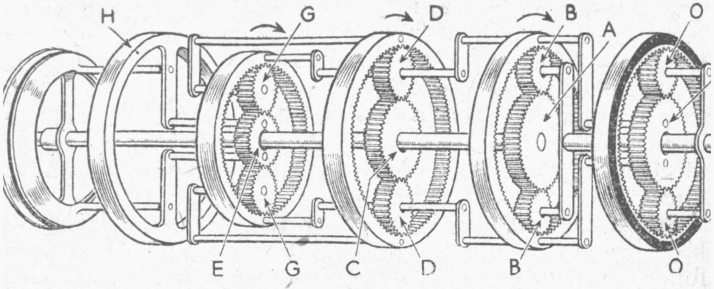
Before entering on a description of the gear box it sho first be mentioned that it is usual to consider the direct of rotation of the crankshaft as viewed from the fro that is, in a clockwise direction. On the other hand, diagrammatic purposes, it is extremely difficult to show a g box except as viewed from the rear, and in order to av confusion the direction of rotation of the crankshaft will called " crankwise " and the opposite direction of rotati " anti-crankwise ", instead of the more usual terms clockw and anti-clockwise.

Referring again to the second drawing it will be seen th a two-speed gear is already possible. If the whole mechanis is locked together so that it revolves as one piece, direct dri is obtained, the propeller shaft running at the same speed the crankshaft, in which case the brake band is not applied.

Secondly, if the brake band is applied to the annulus so to prevent it from rotating, the engine drives the sun whe (A) crankwise and the sun wheel rotates the planet wheels (anti-crankwise ; however, since these latter are in mesh wi the stationary internally cut teeth on the annulus, the plan wheels (B) are caused to rotate round the sun wheel in a crank wise direction, thus driving the propeller shaft. Since th planet wheels are small, and the sun wheel large, the engir revolves a number of times before the propeller shaft com pletes one revolution. This, then, is first speed or bottor gear in the Wilson box, and it is obtained by holding th " first speed annulus " stationary by means of a brake banc

Now examine the next diagram, of obtaining second speed Release the brake band on the first speed annulus and appl another brake to the second speed annulus (again the brak band is indicated by a heavy black line). Now the engin drives the sun wheel C as well as the sun wheel A, causing th planets (D) to run round C in their turn. The spindles or which D rotate are, it is now seen, connected to the first speed annulus, and consequently drive that annulus round.

In the second illustration it was clear how, if annulus, planet wheels, and sun wheels all rotate, and the planet wheels are connected to the propeller shaft, a direct drive is obtained, but now with second speed the planet wheels (D) are connected not to the propeller shaft but to the first speed annulus. Owing to the small size of D with relation to C the first speed annulus will be caused to rotate slowly, and thus second gear is obtained by increasing the speed at which the planets B



Reverse gear necessitates a separate train

(helped by the fact that the annulus with which they are engaged is no longer stationary) run round A.

The all-important point to realise is that second speed is derived from first by " reducing the reduction ", and this is the basic principle of each gear in the Wilson box.

For third speed a variation of the principle is adopted. The brake band for third speed is not applied to the third speed annulus, but to a separate brake drum (H), and this brake drum is connected to the third sun wheel (E) ; E is not keyed to the driving shaft, but is free to rotate or to remain stationary while the shaft is rotating.

When the brake band is applied to H (heavy black lines) the sun wheel (E) is held stationary and the drive now passes from the second sun wheel (C) to the planets (D), which travel round their annulus as before ; however, the spindles of D are connected to the third speed annulus, which is thus caused to rotate in a crankwise direction. Now the third speed annulus is in mesh with the third speed planets (G), and G are in mesh with the third speed sun wheel (E), which is held stationary.

As seen in the diagram, the sun wheel E is smaller than the sun wheel C, and the effect is, therefore, to increase the speed at which the planets D run round the sun wheel C ; it follows as a direct consequence that the speed at which the planets B rotate round A is also increased, thus causing the propeller shaft (connected to the spindles of B) to run faster for the same number of engine revolutions as before. Note here that to obtain third gear two planetary gear trains are used to vary the speed of rotation of the annulus of the original first gear train ; a " reduction of the reduction of the reduction " !

To obtain top gear a cone clutch, shown on the left of the

top gear diagram, is engaged with a coned ring, no bra bands being applied. The cone is equipped with an a positively connected to the driving shaft, and the coned ri is connected to the third speed brake drum (H), while H turn is connected to the sun wheel E. Thus when the clut is engaged E is locked to the driving shaft and the wh mechanism rotates as a small cylindrical flywheel, giving direct drive.

So far the arrangement in which the planetary gears ha been built up to obtain the various forward speeds has be followed through the train of gears. The same use is ma of the various gears and pinions to give a reverse gear. the final diagram it will be observed that a fourth planeta train has been added on the right of the diagram, and that brake band (heavy black lines) has been applied to its annulu

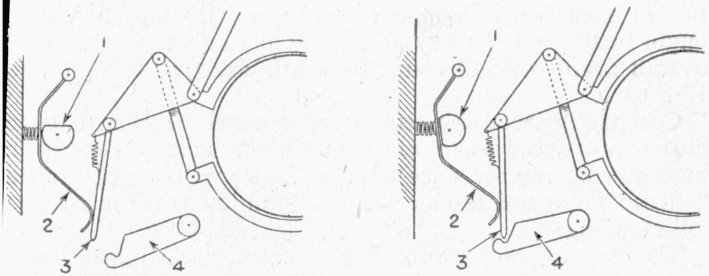
The engine then drives A crankwise as usual ; the plan pinions (B) are driven anti-crankwise, and they in turn dri the first speed annulus round also in an anti-crankwise dire tion. The first speed annulus, is, it will now be seen, connecte to the reverse gear sun wheel M, which is free on its shaft.

Now since the first speed annulus is being driven roun anti-crankwise, the sun wheel M is also rotated anti-crankwis and in consequence the planets O turn crankwise ; but planet O, whose spindles are connected by an arm to the propelle shaft itself, are in mesh with the reverse gear annulus ; thi annulus is held stationary by a brake band, and in consequenc the planets O run round the reverse gear sun wheel (M) in a anti-crankwise direction, driving the propeller shaft also i that direction.

In order to obtain any indirect gear the only movemen necessary is thus to operate a mechanism to lock a brake banc on the desired annulus or drum, all the other brake band being released at the same time ; for top gear a cone clutch is engaged.

The pre-selector mechanism works as follows : By moving the " gear-lever " into the notch for the required gear the driver merely rotates the cam (1) so that in its new position it allows a flat spring (2) to push forward a lever (3), against the action of a light coil spring. The lever (3) is connected by various linkages to the brake band, and it is now ready for the brake band to be applied on that particular gear.

This is brought about by depressing and releasing a pedal similar to the normal clutch pedal, which moves the lever (4)



Diagrams of the selector mechanism before (left) and after (right) moving the " gear lever ". The pedal of course has not yet been touched

sharply upwards under the influence of a very strong coil spring. The lever (4) thus forces 3 upwards, tightening the brake band on to its drum and bringing that gear into operation. The driver can now move the " gear lever " into another notch, without affecting the drive on the gear already engaged.

The corresponding cam is turned and the corresponding lever comes forward ready for engagement, but that lever cannot be engaged by the mechanism corresponding to 4 until 4 has released 3. Now when the " gear lever " was moved the cam 1 returned to its original position, so that the blade spring (2) was no longer bearing upon the lever (3). As soon as 4 releases 3, therefore, the latter returns to its original position under the action of the light coil spring, and is thus carried beyond the reach of 4 until the gear lever is once more placed in that particular notch.

It is usual to fit the control to the Wilson gear on the steering column, just below the wheel.

The overdrive is a modern development on a number of American cars. Its purpose is to provide a very high top gear so that, under easy conditions, the engine may run relatively slowly in relation to a high road speed. Years ago this object was achieved by several gear boxes which had an indirect, or " geared up ", top gear, with the third speed as the normal direct drive. When running in this gear the only reduction of speed ratio between engine and road wheels was that provided by the back axle gearing.

This may be made clear thus : if the back axle ratio is 5 to 1 and the gear box ratios are 1 to 1 (direct), 1·5 to 1, 2·5 to 1 and 4 to 1, the overall gear ratios are 5, 7·5, 12·5 and 20 to 1.

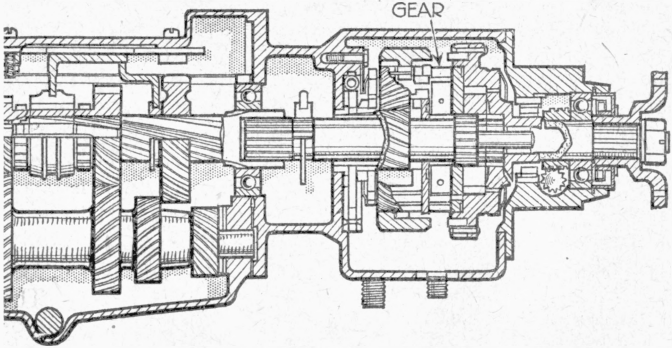
But in a car with an indirect top gear the gear box ratios might be 0·8 to 1, 1 to 1 (direct), 2·0 to 1 and 3·5 to 1, giving overall ratios, with the same back axle ratio, of 4, 5, 10 and 17·5 to 1.

Comparing these two sets of ratios it will be seen that the normal four-speed gear box gives ratios well suited to the modern high-revving engine, since it provides a low top gear and a "close" third and second, with a useful low first for extreme hill-climbing.

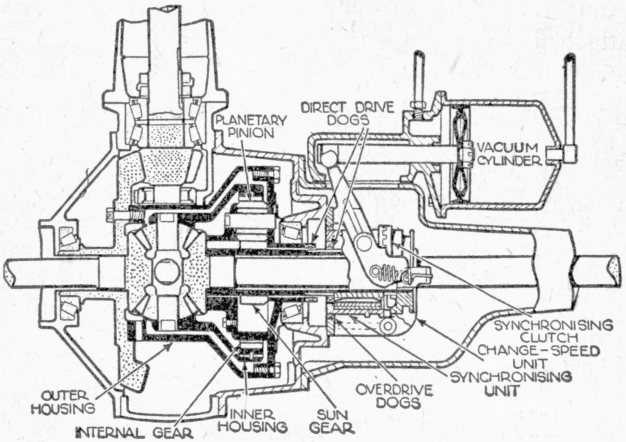
The old type of "indirect top" gear box was current only in the day of the big low-speed engines that were more remarkable for their pulling power than for their r.p.m. Once under way they would pull the high indirect gear, while their slow pulling characteristics did not necessitate such a low first gear as is nowadays regarded as essential.

Modern engines, however, would not be very happy with these ratios, so the overdrive gear box leaves the normal ratios as they were and superimposes a high indirect ratio above the normal direct top gear. Hence the terms "overdrive", "twin top", and so on. The gear ratios therefore would be more of the order 4, 5, 7·5, 12·5 and 20 to 1.

But the overdrive box does something more than this, for it is usual for it to come in and out of action automatically according to running conditions, thereby guarding against either the engine or transmission being unduly stressed by forcing the car to do impossible or undesirable tasks "on top".



In the Chrysler overdrive the unit is located at the rear of the gear box



An overdrive is sometimes incorporated in the rear axle, the planetary gears being part of the assembly of mechanism therein. Unlocking or locking of the sun wheel is performed by a vacuum cylinder

On the Chrysler, which pioneered this device, the overdrive unit is bolted to the back of the normal gear box, and its mechanism embodies an epicyclic gear train associated with a free-wheel clutch actuated automatically by a centrifugal device.

The sun gear is held stationary by a cushion hub, and the mainshaft of the overdrive passes through it. The front end of the mainshaft has splines which engage with the driven shaft of the gear box, and at its rear end it has a spigot bearing in the tail shaft which carries the propeller shaft coupling.

When a control on the instrument board is pulled out, the entire mainshaft slides a little backwards, and serrations on it engage with serrations in the inner member of the free wheel and in the tail shaft, so that obviously the drive is direct from mainshaft to tailshaft, and both free wheel and overdrive are locked out of use.

When the control is pushed in, the mainshaft slides forward, and the serrations on its rear end engage with the inner member of the free wheel and the centrifugal weight assembly. The two weights are held inwards by a coil spring until a speed of 45 m.p.h. is exceeded, when the centrifugal force acting on them forces them out against the spring.

The pinions are held in a cage to which a notched drur attached, and the weights when out try to enter the notc in the drum, although owing to their shape they are una to do so unless the speed of the drum is the same as their o If the driver continues to accelerate, therefore, the overdr remains out of action, but if the driver releases the accelera then the mainshaft and weight assembly slows down and its speed coincides with that of the drum the weight enga in the notches and so the overdrive is brought into action

Power is then transmitted through the mainshaft, t weight assembly, the notched drum, and the planet gears the ring gear, and so the tailshaft, the speed of the latter bei higher than that of the mainshaft and engine.

Just as the overdrive is brought in automatically at 45 m.p. so it goes out of action automatically at 37 m.p.h. The dif rence in these figures is due to a spring-loaded locking b holding the weights " in " or " out ", so that they cann " float ", that is, it gives the weights a definite action.

In another form of overdrive an epicyclic train of sun gea planet pinions and ring gear is incorporated in the final dri and as part of the mechanism within the axle casing. If tl sun gear is left free the whole mechanism rotates as a unit ar the drive is from the crown wheel to the differential and so t the axle-shafts.

A simple vacuum cylinder control with a small lever, fc the driver to operate it when desired, is linked to a slidir dog, by means of which the sun gear can be locked to the ax case, thus holding it stationary. This causes the drive to pa through the planetary gear, giving a step-up drive to the axl shafts, that is, the axle-shafts rotate faster than the crow wheel.

In other cars the object has been achieved by having tw final drives of different ratios, either of which could be use In this case the two final drives double the number of gea ratios available, for the gear box, whether it provides thre ratios or four, transmits them through the " low " or " high final drive according to which is in use.

The overdrive, whatever its operative method, provides very high top gear which would be too high for norm " pottering " but which enables high speeds to be sustained i open country without the accompaniment of great engin speed. The advantages arising from thus allowing th engine to work easily are considerable; wear and tear ar

diminished, and of course as the engine is exerting less effort, it is using less petrol.

During the war years considerable development has been seen in the transmission systems of American cars. Principally these have been in the direction of semi-automatic gear changing, in conjunction with a fluid coupling—itself originally a British development—and obtaining the effect of virtually a two-speed car—one gear for starting purposes and another, of high ratio, for average running. Such a system is particularly well suited to the big engines fitted in the majority of American cars.

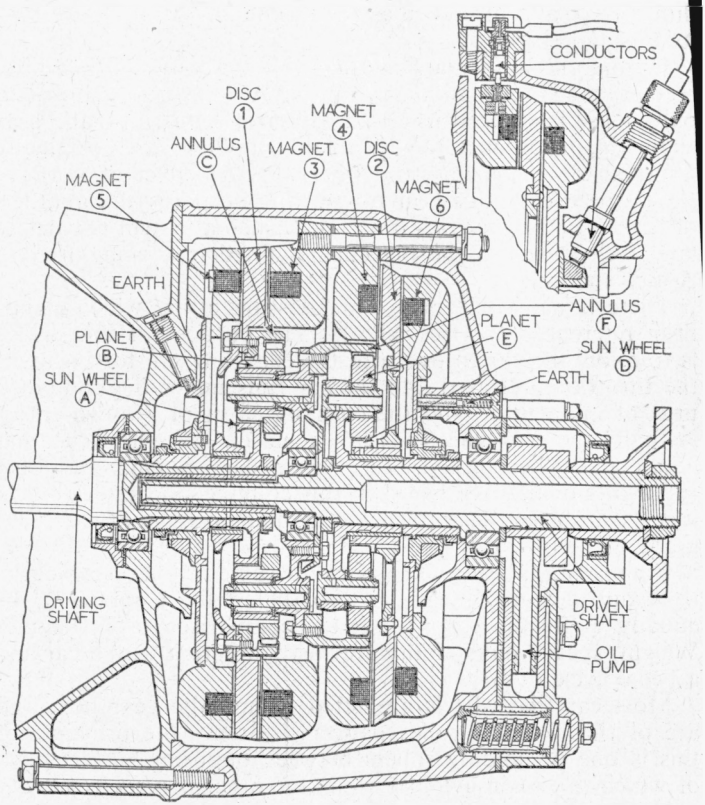
There remains one other transmission fitting which claims brief reference—the free wheel. The purpose of this device is to allow the car to over-run the engine when, for instance, the throttle is released and the car runs under the combined urge of momentum and the coasting effect of a down-grade. Actually the free wheel has not achieved the popularity that might have been expected. Rover cars remain the only exponents of the free wheel in this country, and undoubtedly it is a feature that is appreciated by many owners of this high-grade make of car.

Comparing the free wheel with the same fitting on a bicycle, so many advantages can be seen that it must appear to be equally useful on a car ; but the comparison is not sound. Weight, speed, and stability are vastly different with a car and a pedal cycle.

Most car free wheels are fitted behind the gear box, and are of the jamming-roller pattern. Briefly the principle of this is one of holding rollers between opposing surfaces one of which is a plain cylinder while the other is a ring of " saw teeth ". Between the two surfaces, therefore, is a series of wedge-shaped spaces, in each of which is placed a steel roller.

When the driving member rotates in its normal direction the angle and disposition of the teeth is such that the rollers are carried into the tapered ends of the recesses, where they jam between the teeth and the inner cylinder and transmit the drive. If the driving member rotates in the opposite direction, or if the driven member overruns it (which amounts to the same thing) the rollers are carried into the wide ends of the recesses and no drive is transmitted, that is, " free wheel " action takes place.

It is vitally important that a car free wheel should be controllable by the driver, that is, that he should be able to lock



A section of the Cotal gear box, showing the arrangement of the various parts with, top right, the method of connecting the electric cables to the stationary and rotating magnets

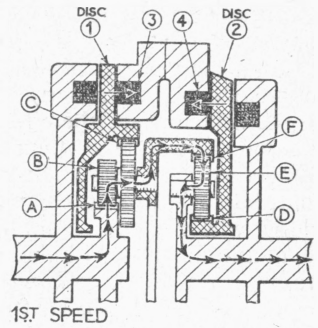
it when he needs a solid drive, as when reversing or when a steep hill has to be descended.

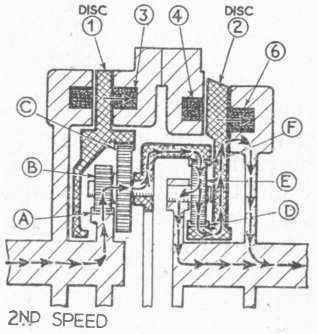
The Cotal gear box differs from any other in three respects. The gears are put into action by electromagnets, the driver operating a gear lever which is in effect merely a switch directing current to the selected magnets ; and secondly, there are only two trains of gears, that is, sets of planetary gears very similar to those already described in connection with the

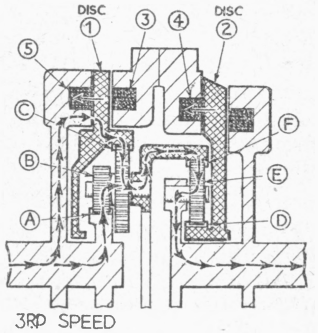
Wilson box, but these two trains give four different ratios, and thirdly, the reverse mechanism is outside the box.

Turning now to the diagram, each gear train consists of a sun wheel, a set of planet gears and an internally-toothed ring or annulus. On first speed, the current is switched to the fixed electromagnet 3 and disc 1 is held to this magnet and thereby stopped. Bolted to disc 1 is the annulus C, which also stops. At the same time, current is directed to fixed magnet 4, thereby stopping disc 2, and the sun wheel D connected to this disc. As a result, the drive passes from the driving shaft to sun wheel A, and this causes its planet wheel B to revolve and to run round annulus C.

The planet wheel, it will be noticed, consists of two gears, one small, meshing with the sun wheel, one large, meshing with the annulus. These gears run round the annulus. They drag the carrier, in which are their spindles, round with them. The carrier in turn causes annulus F to rotate. Annulus F drives the planet E, which runs round the stationary sun wheel D. The carrier for planet E therefore runs round as well, and as it is fixed to the driven shaft, the latter rotates and so drives the propeller shaft and the car, the effect being a very low gear ratio.







Diagrams of Cotal box showing the drive on first speed; how the drive passes through the gears on second speed; and third gear in operation

For second speed, disc 1 remains locked electrically to fixed magnet 3, but disc 2 is released from magnet 4 and held by rotating magnet 6. Magnet 6 is attached to the driven shaft and as the planet carrier of this train of gears is also attached to the driven shaft, the effect of holding disc 2 to magnet 6 is to lock the whole of the second gear train solid, so that it rotates as one mass. The drive then passes from the driving shaft sun wheel A to the planet wheels B, as before, and the planet wheels B run round their locked annulus C, taking with them annulus F, but as the planet and sun wheel of the second train cannot rotate, the whole of this train runs round as a mass, and the driven shaft is rotated at a higher speed than before.

For third speed, disc 1 is held to rotating magnet 5, and as magnet 5 is part of the driving shaft, as also is sun wheel A, this time the first train is locked solid. At the same time, disc 2 is locked to stationary magnet 4, thereby stopping sun wheel D. The driving shaft then rotates the first train of gears as one solid mass, thereby drives annulus F and causes the planets E to run round the locked sun wheel D. As a result, the driven shaft is rotated by the carrier of sun wheel D at a still higher speed than before.

For fourth or top gear, disc 1 remains locked to rotating magnet 5, disc 2 is locked to rotating magnet 6, so that both trains of gears run solid and the drive passes from the driving shaft to the driven shaft direct ; in other words the two rotate at equal speed and you have the highest gear of all.

Reverse is operated by a separate train of gears altogether, consisting also of a sun wheel, planets and an annulus, so arranged that either the whole gear is locked solid, in which case the car is driven forward, or the gear train is in operation with the planet carrier stationary, in which case the car is driven backwards. This reverse train is placed either between the clutch and the gear box or between the propeller shaft and the final drive, and the switch gear lever is so designed that only first and second gears can be brought into operation for reversing.

Advantage is also taken of this separate reverse mechanism to provide a neutral gear. Forward, reverse and this neutral are selected by a lever, additional to the gear lever, which, for neutral, slides the planet gears of this train out of mesh, so that no drive is transmitted to the rear axle. Normally, of course, the equivalent of a neutral can be obtained if none of

magnets of the gear box is operated, but in that case all gears in the box rotate without the car being driven either ward or backwards.

There is a reciprocating oil pump operated by an eccentric the driven shaft to force oil to the bearings of all the gears ; d electric current is delivered to the magnets by a simple nection in the case of magnets 3 and 4, which always nain stationary, by a brush pressed against a ring in the se of magnets 5 and 6, which rotate. Having passed round e coil of wire in the magnet, the current returns to the chassis the car through the stud that holds the stationary magnets d through brushes held against rings on the rotating agnets.

It will be seen that in this gear mechanism the gear control ver can be placed anywhere desired, quite easily, on the strument board, for example, or in the centre of the steering heel, or underneath the steering wheel on the steering column ; nd instead of a lever, push buttons, numbered or lettered cording to the gears, can be used.

As the years go by, so the signs that the ordinary clutch and ear box will eventually vanish become more definite. That ne gear change will be practically automatic is certain, and is highly probable that the clutch pedal, last of the controls o need any real physical energy in operation, will disappear s well.

As things stand, the so-called torque converter shows onsiderable promise. This mechanism is really very simple, nd akin to the fluid flywheel, which has been described lready. The clutch, as hitherto known, is eliminated. The lywheel drives a disc in which are formed a number of curved ubes or passages as shown at (A) in the accompanying llustration (page 135). If you imagine this disc rotating at nigh speed in a casing which contains oil, you will see that the oil is picked up by the tubes, because centrifugal force tends always to throw the liquid outwards, and that owing to the shape of the tubes it emerges at the top in the form of a ring of jets. Supposing the jets were allowed to play on the vanes of another disc coupled to the transmission of the car, then the second disc would be turned and would drive.

But in practical fact the thing is not quite as simple as that. The ring of jets at (A) discharge oil at passages in a second disc (B) and in the process drive (B) in the same direction as (A). But on leaving the passages in (B) the oil passes through

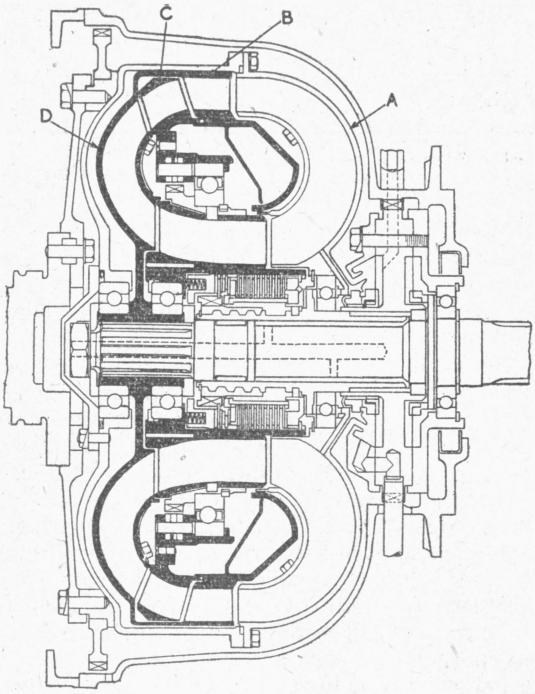
another series of passages in disc (C), the shape of th passages altering the direction of the oil so that it can p upon passages in a fourth disc (D) and drive this disc rou in the same direction as (B). The two discs (B) and (form the two stages of the driven section of the mechanis and they are attached to the propeller shaft, which in tu drives the bevels and so the car.

The intermediate (C), however, performs a special servi In the ordinary way the force of the oil thrown from (would cause (C) to revolve in a direction opposite to (This is prevented by the fact that (C) is connected to the cent shaft of the car by a free wheel and the free wheel is set that (C) cannot rotate in the reverse direction. The fr wheel, incidentally, is formed as a multi-disc clutch and n quite as the usual free wheel of the bicycle.

As long as the car is difficult to drive because of the loa or the gradient, or because it is being accelerated, the drivi disc (A) rotates with the engine at high speed, and the c consequently exercises maximum thrust on (B) and (D), whic is really the equivalent of having the engine driving throug first gear. As, however, the car accelerates, or maybe th gradient eases, so the driven discs (B) and (D) increase spee until finally the car is running with the throttle back and a the discs are at the same speed, which is the equivalent of th top gear of an ordinary gear box. To make this effective disc (C) is now able to rotate at the same speed as (A), (B) an (D), because the free wheel comes into operation. The momen the load on the car makes itself felt, the transmission in effec reduces the gear ratio, (A) running faster than (B) and (D) while (C) is held stationary by the free wheel.

Thus arranged, the gear is in effect automatic. It adjust the ratio of the drive to the circumstances without the drive doing anything.

But of course, a gear of this type does not reverse, and so behind the torque convertor there has to be an ordinary reverse gear, which is brought into action when required, but which will also serve to disconnect the engine entirely from the final drive, as is done when a normal gear box is in neutral. Incidentally, it would be possible quite easily to arrange for one lower ratio through gearing, should that become absolutely necessary. The chief reason for this extra mechanism is, however, the reverse, because if the engine is allowed to run quite slowly and the hand brake is kept on, the car will



Diagrammatic section of a torque converter. The engine drives a circle of jets, shown at A, and these jets project oil at the circle of passages in another disc, shown at D; the effect being that A drives D, while D is coupled to the propeller shaft of the car

not move forward and the equivalent of neutral is obtained without additional mechanism.

So far, a gear of this description has not the efficiency of the ordinary clutch and gear box. Its appeal is solely on the score that it is automatic and that such fatigue as is created by constant use of the clutch pedal is avoided. The whole gear is concealed within a casing, is of no great size, and the casing is full of oil, the mechanism being such that it is unlikely to require much attention even after a very considerable mileage, always provided that the means adopted to prevent the oil from leaking away is entirely efficient.

CHAPTER 7

The Final Drive

HOW is the power developed by the engine and transmitted through the clutch and gear box finally taken to the road wheels ? This is the next question to which an answer must be provided, but before going into details there are two points that may well be considered.

In the first place, the engine, clutch and gear box are so placed in the frame of the normal car that the various shafts in them—crankshaft, clutch shaft, and gearshafts—are parallel to the fore and aft centre line of the chassis, whereas the back axle is at a right angle to it. Also, the engine, clutch and gear box are positively located in the frame of the car, while the back axle is flexibly attached to it by springs, in order that pot-holes and bumps in the road surface shall not cause discomfort to the occupants of the car. Accordingly, it is necessary to employ some mechanism which will allow power to be transmitted through a right angle, and which will accommodate relative movement between the driven shaft of the gear box and the back axle.

On a few cars, however, the gear box is mounted separately from the engine, and on rough ground the frame of the car may bend or twist slightly, so momentarily throwing the gear box out of line with the clutch shaft. Accordingly, in such cases the shaft which runs from the clutch to the gear box has

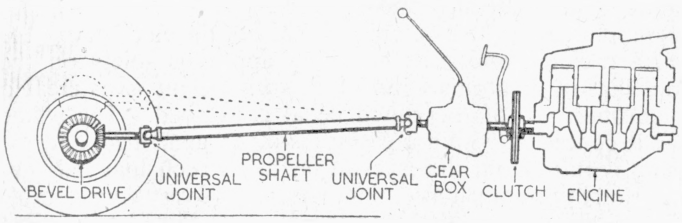
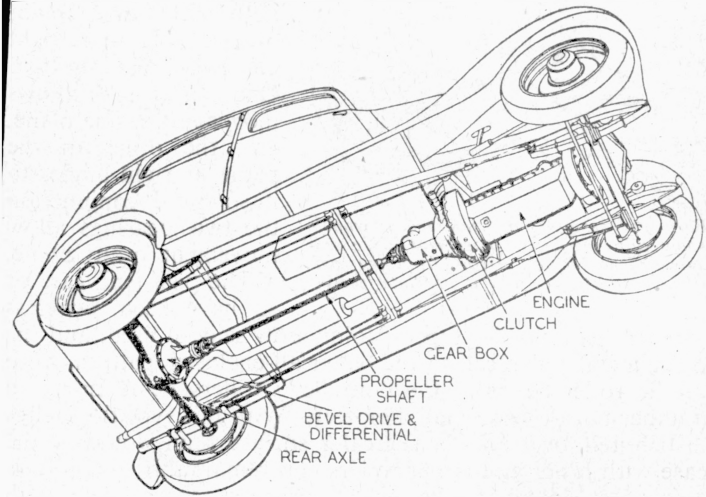


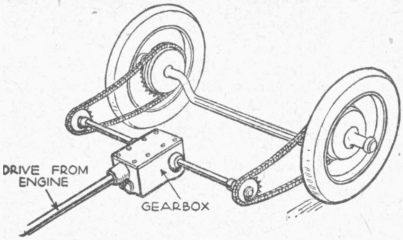
Diagram of open shaft drive ; the propeller shaft must be free to move



Study of the final drive in this chapter completes the explanation of the means by which motive power reaches the road wheels. Here is seen the transmission layout of a typical car

to be provided with means for allowing this small misalignment to take place ; this is accomplished by means of a flexible coupling, and usually such a joint is used on each end of the shaft. The simplest form consists of a leather or fabric disc, carried between two- or three-arm stars or "spiders" and although it was originally in general use as a universal joint in the final transmission it was not very long lived and has become rare.

Relative movement between gear box and back axle is of much greater amplitude than in the case of a clutch shaft, and couplings known as universal joints, which permit of considerable angular movement between the shafts, are therefore used, one being on the gear box tailshaft and (according to the type of propeller shaft which joins the gear box to the back axle) probably another at the rear coupling also. Accordingly, one is fitted on the end of the driven shaft which projects from the back of the gear box, and it couples this shaft to the propeller shaft, which transmits the drive to the back axle. Practically every car to-day is fitted with mechanical universal



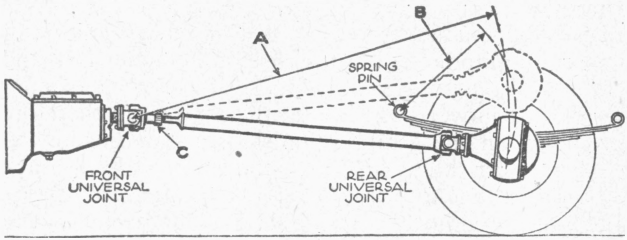
Early car designers had no need to trouble about allowing for the movement of the rear axle. Twin chains driving from the gear box permitted the axle to oscillate freely

joints, consisting es
tially of two pi
bearings placed at ri
angles to one anotl
One bearing allc
movement in one pla
and the other in
plane at right angles
it, so that in conjunct
the two bearings all
movement in any pla

The past ten years so have seen progr
from the flexible disc type of joint, now seldom used, and t
plain metal universal, to the better all-enclosed pattern, wi
needle roller bearings, the "needle" rollers being many
number but of very small diameter. With this type the load
distributed over a much greater surface than would be t
case with fewer and larger rollers and remarkably long life
assured. Moreover, the needle bearings are packed wi
lubricant and enclosed, so that lubrication is not require
between overhauls.

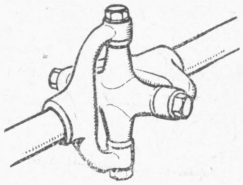
Another type of universal joint that has become increasing
popular, although chiefly used on buses, is the Layrul
This to some degree is a combination type, for it uses resilie
bushes, although in design it is more "mechanical" than tl
flexible disc arrangement.

It consists of two opposing "star" members having sho
studs projecting from the arms, and these engage with rubb
bushes carried in a disc. Considerable shaft angularity ca



When the final drive is "open" the rear axle pivots round the radius B, but the propeller shaft strikes an arc of radius A. Thus the length of the shaft varies, necessitating a sliding joint (C)

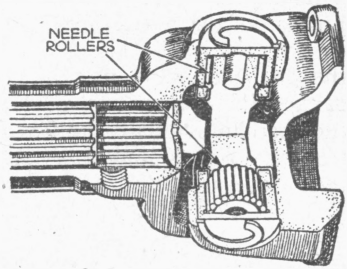
e accommodated ; it does not re-uire lubrication or adjustment ; it is asily dismantled, and is silent in peration.



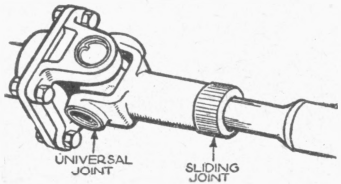
A plain metal universal joint of the simplest type

The provision of one joint, behind he gear box, might appear to be enough for all purposes ; for the purpose of accommodating axle oscillation, so it is. But this is only half the task on the majority of cars on which what is known as the " open " propeller shaft (or " Hotchkiss drive ") is used. With the open shaft final drive the torque reaction—that is, the tendency of the axle as a whole to rotate in the opposite direction to the road wheels—is resisted by the springs ; this twisting is clearly visible in many cases, particularly if the driver is ungentle with his clutch ! Conversely, twisting in the normal direction of rotation is apparent when the brakes are applied. A universal joint at each end of the propeller shaft is therefore necessary.

Axle movement due to road inequalities is approximately vertical, and not, as might be supposed, in the arc of a circle



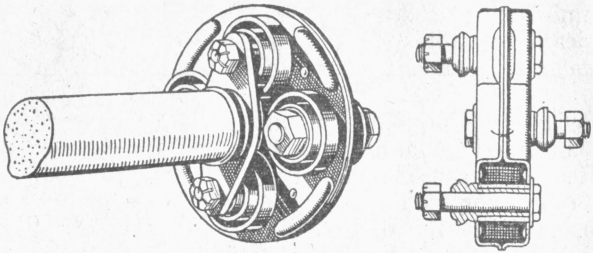
Part section of the joint on the left showing the needle-roller bearings and the splined sliding attachment to the propeller shaft



Incorporating a sliding connection, a modern design of needle roller universal joint (above). The capped roller races are retained, like some gudgeon pins, by " circlips "

of which the front universal joint is the centre ; so that its distance from the front coupling is constantly altering. For this reason provision must be made to allow the length of the propeller shaft to vary, which is easily arranged by incorporating a sliding joint with the forward universal, the centre boss of which slides on splines on the end of the shaft.

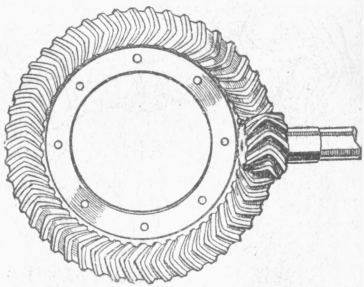
At the rear end of the propeller shaft there must obviously be the means for transmitting the power through a right angle,

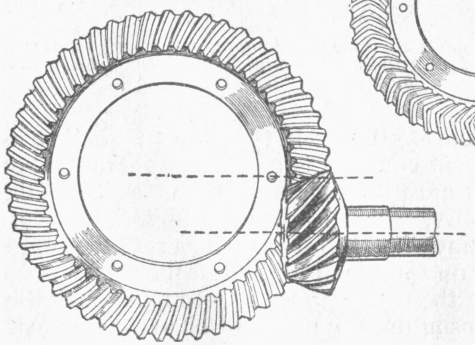


Layrub universal uses resilient bushes

and this is accomplished by means of bevel or worm gearing. Bevel gears are so named because they have teeth on bevelled (or mitred) faces. One wheel is made considerably smaller than the other to allow the engine to run at higher revolutions than the road wheels when the top, or direct, gear is employed. The ratio is usually about 5 to 1 and the smaller wheel is known as the bevel pinion, the larger being the bevel wheel, or crown wheel. The bevel pinion is coupled to the end of the propeller shaft and the crown wheel is on the shaft that carries the road wheels. The teeth of straight bevels take the load individually, tooth by tooth, but helically cut gears transmit power smoothly and progressively with an overlap over several teeth, consequently tooth impact is reduced,

(Below) Hypoid or "off-centre" drive which has the advantage of a low propeller shaft level

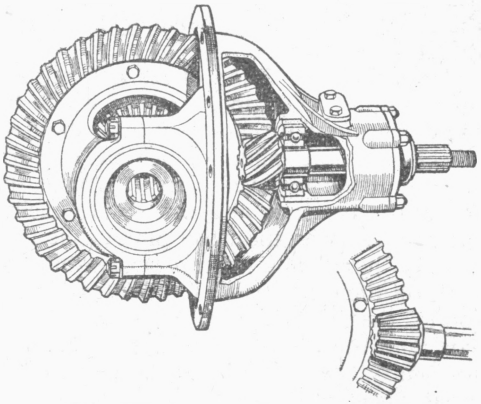




(Above) Double spiral bevel or "herringbone"; very silent but expensive

peration is silent and the life is prolonged. Spiral bevels re now almost universal.

A drawback to the normal bevel drive axle is that in a low-lung car a tunnel, more or less deep according to the build f the machine, must be provided in the floor of the car to ive room for the up-and-down movement of the propeller haft. A very much lower floor ine is possible with the hypoid bevel, which has a special form of spiral tooth that allows the pinion shaft to be placed well below the centre line of the crown wheel. For that reason and other advantages such as silence, freedom from vibration and long life, the hypoid bevel is being more widely adopted on the latest designs.



Spiral bevel differential assembly, the most widely used of all final drives. The edge of one differential pinion can be just seen, and also the splined socket for one of the driving shafts

(Bottom right): Close-up of a straight-tooth bevel gear

Worm drive is used by a few car manufacturers because of its silent running. The worm is coupled to the end of the propeller shaft, and may be described as a form of screw. It is made of steel, and engages with either the top or bottom edge of a bronze worm wheel fixed to the axle shaft ; the worm wheel has a form of gear teeth of a shape to mesh with the worm itself. High cost and relatively low efficiency have prevented the general adoption of worm drive, in spite of its silence and the low level propeller shaft that can be used (if loss of ground clearance is not regarded as objectionable).

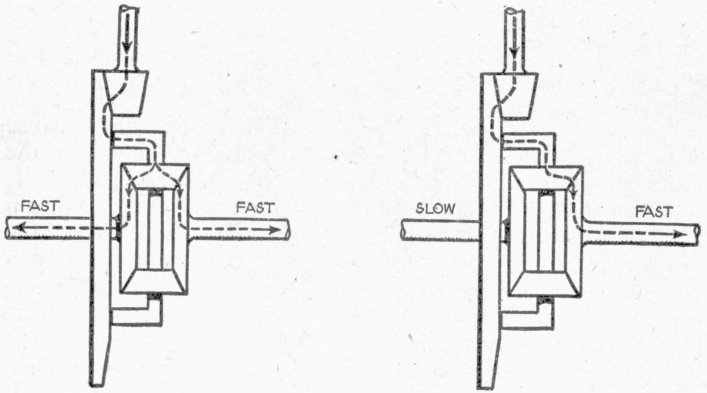
Next there is another important mechanism to be dealt with. When a car turns a corner, obviously the wheel on the outside has to cover a greater distance than the wheel on the inside ; if the rear axle consisted merely of a plain shaft with

a road wheel at each end and a bevel wheel or worm wheel in the centre, one of the road wheels would have to slip on the road surface in order to keep step.

Accordingly, use is made of a differential gear. The rear axle-shaft is divided at the centre, and the ends of the two driving shafts are connected through the differential gear to the crown wheel or worm wheel as the case may be. This gear allows the rear wheels to revolve at different speeds when the car turns a corner, while at the same time both wheels are driven by the engine.

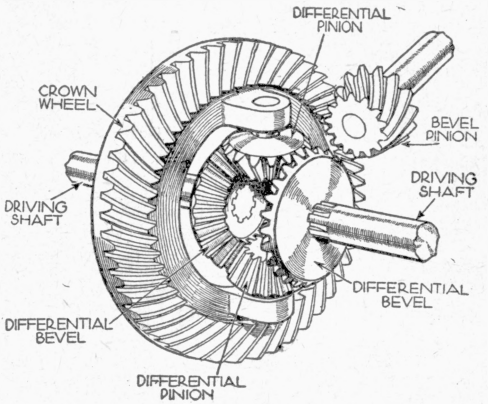
To explain the action of the differential, imagine two shafts on the same centre line, each of which has a bevel wheel on the end nearest to its fellow. Meshing with these two bevel wheels is a bevel pinion which has a bearing in a ring or case surrounding the bevel wheels. If the shafts are freely supported in bearings and can rotate easily, then, on rotating the ring carrying the bevel pinion, the three bevels will rotate as one, there being no relative movement between them.

If, on the other hand, one shaft is gripped so that it cannot rotate, then the bevel pinion will be forced to rotate on its axis, and thus, as it were, " walk round " on the teeth of the stationary bevel wheel. In doing this it will cause the other bevel wheel and shaft to rotate (actually at double the speed of the crown wheel), and if a road wheel is placed on the

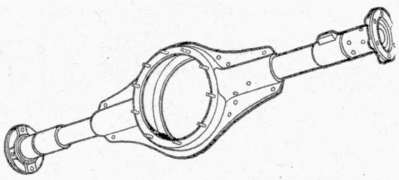


When a car is travelling in a straight line, the same driving effort passes through both axle-shafts. On turning a corner the inner wheel necessarily revolves at a slower speed, and to distribute the torque at these different speeds, the balance gear comes into play

outer ends of the shafts it is easy to visualise that this is the condition obtaining when a car is turning such a sharp corner that one wheel is stationary. The ring carrying the bevel pinion is attached to the crown (or worm) wheel; in actual practice two, three or possibly four, bevel pinions are used, all carried by the same ring.



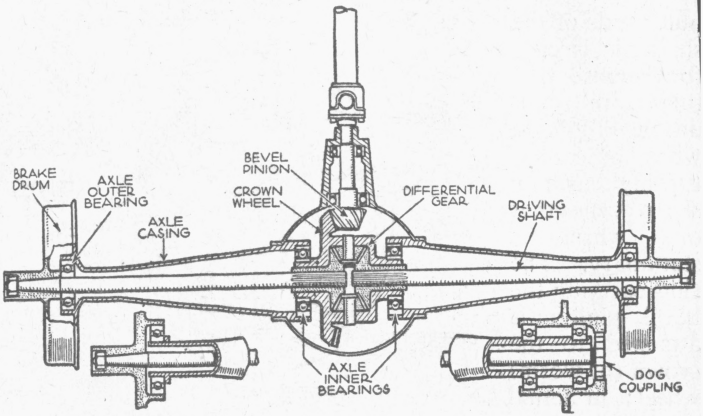
A spiral bevel differential assembly. The silence of the spiral bevel results from the extra length of tooth and the fact that more than one tooth is sharing the load at any moment



A built-up " double-banjo " axle casing

The shafts and gears are supported in the axle casing, which may be formed of welded steel pressings or of aluminium castings and steel tubes bolted together. Bearings are provided for the short shaft carrying the bevel pinion, for the differential casing carrying the crown or worm wheel, and for the driving shafts, to the outer ends of which are fitted the hubs carrying the wheels. In the arrangement of the details there is, of course, much variation, especially in the manner in which the bearings for the different parts are arranged.

On some cars the centre portion of the axle casing is extended forwards to form a torque tube round the propeller shaft, and the head of the tube is usually formed as a ball which fits into a steel cup at the back of the gear box. This ball joint, as it is called, surrounds the universal joint coupling the gear box driven shaft to the propeller shaft, and it is itself a form of universal joint, so that the movement of the rear axle is not restricted.



Both three-quarter floating and full floating axle construction is shown in this drawing. On the left is the three-quarter floating. A bearing in the hub is located on the outside of the axle casing so that the bulk of the weight is carried directly thereon. The axle-shaft is rigidly fixed in the hub, however, and it bears some of the weight due to overhang and also, through its inner bearing, it has to maintain the alignment of the wheel

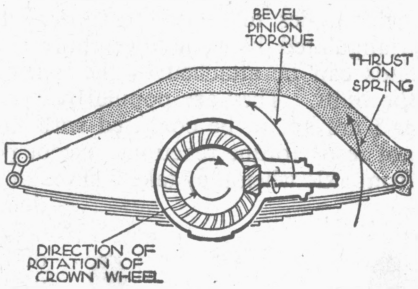
On the right is shown full-floating construction, the hub being carried entirely on bearings external to the axle casing. The axle-shaft carries no weight, and has no function except to drive the hub through an integral dog or driving plate on its outer end. Full floating axles are expensive, but have many advantages mechanically, not least that axle-shafts can be withdrawn and replaced without even jacking up the car, removing the wheel or unloading the vehicle. They are therefore universally used on buses and heavy lorries, but seldom on cars

The whole of the final drive system depends upon the way in which the torque reaction is absorbed. For example, half-elliptic rear suspension, being massive, is mechanically the most suitable where the springs have also to take the torque reaction stresses. On the other hand, if the propeller shaft is enclosed in a torque tube all the stress can be absorbed by this component and the springs have no extra function put upon them.

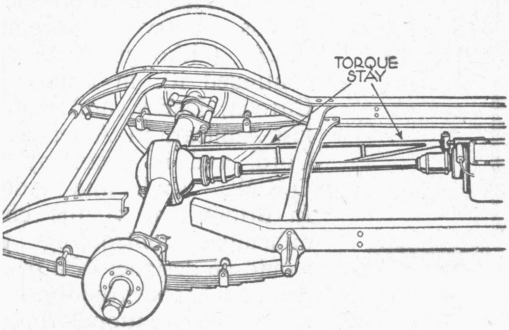
When a torque tube is used a single universal joint at the front end of the propeller shaft is sufficient. The torque tube is attached to a frame cross-member by a ball and socket or trunnion joint.

A further scheme is the use of torque stays anchored to the frame at each side just alongside the road springs. Pivoted

arings at the point attachment permit ovement with the ring deflections. hers use triangulated rque rods, the apex ing attached by a ll-jointed coupling a point in line with e centre of the uni- rsal joint at the back the gear box while e outspread ends are ted above and below e differential casing the back axle.

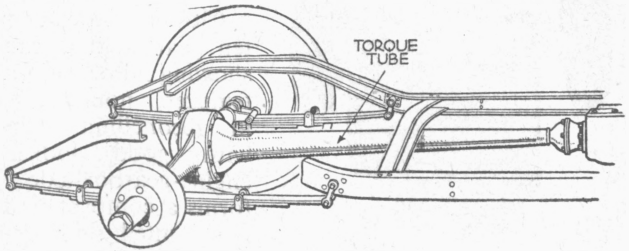


Driving torque on the axle and spring components, shown diagrammatically. Braking torque reverses these forces



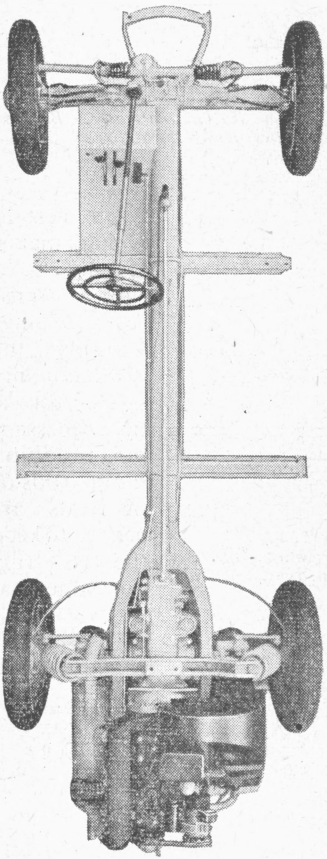
stout girder-like member of triangular shape, hinged at apex, is used in this design to resist the drive and brake torque

On certain popular makes of cars fitted with transverse springs (notably the Ford) not only is a torque tube necessary but in addition radius rods or tie rods are needed to keep the axles truly positioned at



The more familiar type of torque member is a tube surrounding propeller shaft, fixed to the axle and pivoted to the gear box

right angles to the centre line of the car. These rods are triangulated, being arranged horizontally so that the outspread ends can be attached to the axles as closely as possible to the hubs. They are popularly referred to as "wishbones" and are apt to be confused with torque arms, but they do not resist torque reactions, except possibly in the case of the front axle when they take a share in resisting the displacement due to braking torque.



Plan view of the rear-engined Mercedes as built before the war

In quite a number of cars of various countries the conventional mounting of engine and driving wheels at opposite ends of the chassis has not been followed. Some makers place both engine and drive at the same end, and front-wheel drive cars have been produced in this country by Alvis and B.S.A. (although Alvis discontinued it), in France by Citroen, Derby, and Hotchkiss-Amilcar, in America by Cord, and in Germany by D.K.W., Audi and Adler. In Britain one of the chief difficulties confronting the would-be designer of a front-drive car has been the objection to an unconventional appearance, for the public takes a good deal of educating to a radical outward change.

Citroen first produced some ten years ago a car which, showing numerous interesting features, notably succeeded in reconciling front drive with good looks. The engine-gearbox-axle system forms a compact unit, which is mounted on four massive bolts at the fore end of the steel body-chassis shell. The

rear wheels have thus no function other than to act as a trailer. Consequently an exceptionally low floor level is possible without any such obstruction as wells, propeller-shaft tunnels and the like, and this applies to both front and rear compartments.

The alternative to front drive is the transfer of the whole mechanism to the rear end of the car. This layout was developed extensively in Germany and Czechoslovakia but elsewhere experiments were tentative, and once more one must attribute this to reluctance to endorse the unusual.

The little 1,679 c.c. Mercedes represented a neat rear-engine design. The engine was quite orthodox, a four-cylinder water-cooled unit with an ingenious cooling arrangement (cooling is usually the major problem with rear-engine design).

A " backbone " frame—to be dealt with later—with two cross-members, a platform for the pedals and the driver's feet, and a cradle carrying the drive unit, was used, rather resembling a giant toasting fork seen from above. This car is interesting in providing an example of " inter-axle " seating ; true inter-axle seating is that in which the passengers on both front and rear seats are within, and not partly over, the axles ; this position gives maximum freedom from " bounce ", and therefore maximum comfort.

In Czechoslovakia Tatra cars were developed with rear-mounted engines, in both small and large sizes, and it seems likely that in due course cars will be made in this country with this arrangement of the power unit.

CHAPTER 8

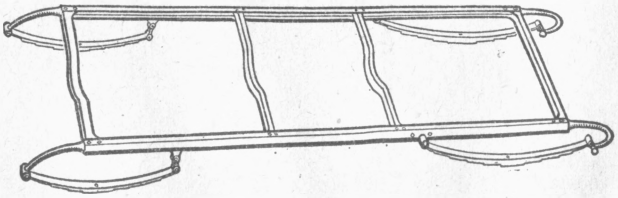
Frame and Springs

REFERENCE was made in the last chapter to the frame of the car. This serves as a foundation which carries the engine, clutch and gear box, the radiator, wings, running boards and coachworks, just as the frame of a bicycle carries the wheels, handlebars, saddle and mudguards. The complete assembly of the mechanical parts of a motor car, excluding bodywork, mudguards, etc., is known as the chassis.

The frame of the modern car is constructed of steel pressings bolted, riveted, or welded together. In the design of frames there is much variation, for the shape of the many other parts carried by the frame has to be taken into consideration. In particular the type of springs used will affect the design although the majority of cars have half-elliptic springs, so called from their shape.

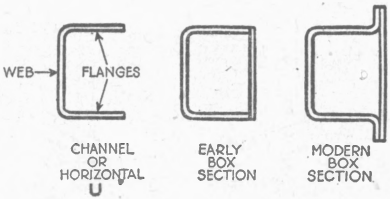
The frame in such a case will be roughly rectangular if viewed from above, the long sides of the rectangle being the main frame members, or side members. The brackets in which the ends of the springs are pivoted at the extremities of the main frame members are known as dumb irons, while the shorter lengths of steel tube or channel that join the side members together are the cross-members.

As will be shown later, the front wheels have to be capable of turning sideways to a considerable extent in order to steer the car, and therefore the frame at the front must be made fairly narrow in order to leave room for this movement. At



Early frame of rectangular construction with added dumb-irons fore and aft to take the springs and very weak cross-members

e rear, however, the ıme members should be wide apart as possible, as to give a wide base r the body and to ıpport the weight as ose up to the wheels as ɔssible. It is usual, ıerefore, for the main ame members to be ırved in, or inswept, at ıe front, and they are equently curved upwards, or upswept, over the back axle, so s to allow room for the axle to move up and down on its ɔrings. Sometimes the main frame members are kept straight, s seen in plan; but are set closer together in front than at the ear, that is, the frame tapers outwards from front to rear.



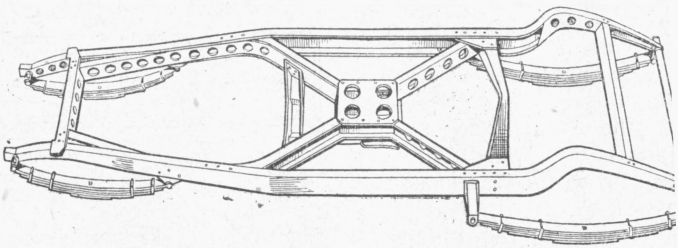
Channel section frame members have developed into a stout box type in which lips are formed on the flanges to which the back plate is welded

After the introduction of the frame built up with channel ection side-members there was for a long time very little real ɔrogress in frame design. Probably this was owing to the act that the stresses to which the frame is subjected were not horoughly understood, for it must be realised that the problem s different from a case of, say, a beam or girder in a building. The essential difference between the frame of a car and a beam n a building is that the car frame is supported on its two axles ɔn springs, and that the axles are subjected to vertical move- ment according to the roughness of the road surface, whereas a beam in a building is rigidly supported and is at all times carrying a steady load.

As the weight of only a medium-sized car may be well over a ton, and as the car may be required to travel at 60 m.p.h., it will easily be understood that the wheels, axles, springs and frame will be subjected to considerable stresses each time that a wheel suddenly drops into a pothole or encounters a bump.

Thus it was not unknown a few years ago for channel section steel frames to break their main side-members, for the simple reason that the stresses set up in the frame had been underestimated. Obviously, a frame which is supported at its ends tends to bend or sag in the middle, and cases of fracture in main frame members usually occurred amidships.

One of the first steps forward in frame design was to increase the depth, that is, the web, of the channel section. Then other improvements began to be made, for it was realised that

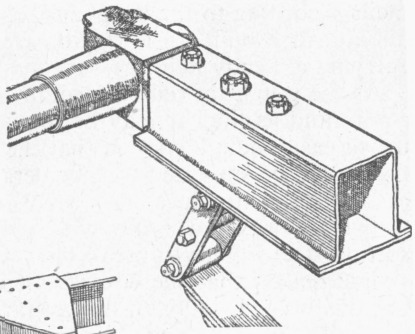


Cross-braced box section frame with additional front bracing. Weight saved by drilling the webs of the channels

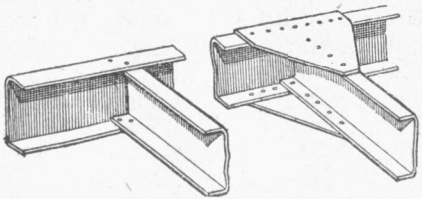
a frame was not only liable to bend, but also to twist and t "lozenge", that is, for the rectangular form to tend at time towards the diamond shape.

Accordingly, more attention began to be given to th disposition of cross-bracing, and to the way in which cross members were attached to the main frame. In the early day cross-members were rather looked upon as being necessar merely to tie the main members together, and to form a basi for some of the other units of the chassis. For example cross-members were frequently made use of to carry the gea box, which was separate from the engine and clutch.

This introduces a point of which sight is sometimes lost namely that the modern form of construction, in which engin and gear box form a unit, has had an effect upon frame design Very much so, also, has the modern method of mounting the power unit on rubber, for when the engine was rigidly bolted to the frame members it served to brace them together.

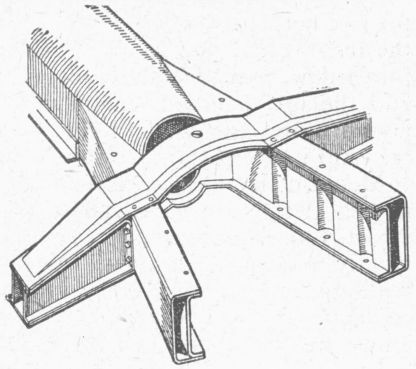


Box section frame with tubular cross-member

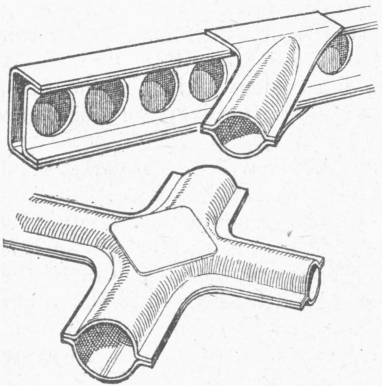


(Left) A right-angled joint such as here seen is apt to be weak unless strengthened with gusset plates

Indeed, as design gradually changed, so have frames developed, and new problems have arisen for solution. For example, owing to the demand for cars of lower build, with a lower centre of gravity, and, therefore, greater stability on the road, the frame is curved down behind the front axle then up in front of the rear axle, a construction referred to as double-dropped.



A tubular "backbone" frame of box section splayed out into a fork and braced by a cross-member at the rear end



Tubular cross-bracing of ingenious form used in conjunction with drilled box-reinforcing side-member

Some early double-dropped frames were apt to be weak in the neighbourhood of the first drop. Greater strength was attained by increasing the depth of the web and the width of the flanges at such points.

Obviously, the manner in which the cross-members are attached to the main members has a bearing on the resistance to the trouble known as "lozenging". A channel section cross-member attached to the side-members merely by a couple of rivets through the flanges of the sections would obviously be much weaker than an attachment making use of corner or gusset plates, as shown in the accompanying diagrams. Similarly, the use of a tubular cross-member at suitable points will increase the resistance of the frame to twisting stresses due to road inequalities.

So gradually, as the stresses to which a frame is subjected

became better understood, methods were evolved of increas the resistance of the frame. Eventually two important st forward were made—the adoption of box section memb and the use of cruciform bracing, both these developme giving more strength and rigidity to the frame without creasing its weight appreciably.

Mention should also be made of a manufacturing proc namely, welding, which really made the box section possil Apart, too, from that aspect, welding processes have been greatly improved that they are being widely used in t building up of frames, giving stronger and better joints th could be obtained by riveting. The disadvantages of rivet joints are that holes must be drilled to take the rivets, a holes through the flanges are undesirable. There is alwa the possibility of the rivet not properly filling its hole, which case that rivet will be useless and the other rivets in t particular joint will have to share between them some of t work that the faulty rivet should be doing.

What is a box section? To the non-technical the answ may be best given by saying that the description of ordina channel as U section is self explanatory, while if the ope side of the channel is filled by welding in a steel plate it becom of box-like form.

The strength of the resulting section will, of course, depen partly upon the manner in which the extra side is welded ir and this may be done in as simple a manner as possible b taking a plain channel section and a strip for the fourth sid just wide enough to allow the edges of the strip and of th flanges of the channel section to be welded. On the othe hand, the channel section may have lips specially formed o the flanges so that a fourth side can lie against them, allowin good spot-welds to be made electrically along the lips.

Frames with cruciform bracing came into prominence a few years ago. They can be built up in a number of ways, and a popular method is to bend two channel section members so that each forms a wide-angled V. These are placed point to point and united by plates riveted or welded to the flanges, and the cruciform member thus resulting has the four ends then riveted or welded to the flanges of the main frame members.

Frequently this cruciform member has its channels arranged so that the flanges run towards the flanges of the main members, and the ends of the cruciform are then often continued along

inside the channel of the main members, thus forming a box section at these points.

What may be regarded as a further development of cruciform construction can be seen in the Mercedes and Hansa chassis, with frames which are really a cruciform construction in themselves. The main side-members converge together from the front, are united just after amidships and then diverge towards the rear wheels. These waisted frames, as they might be termed, seem to have the rigidity of an orthodox frame with cruciform cross-bracing, and the Mercedes example is particularly interesting, since it is of welded tubular construction, the main members being formed of oval section and the cross-members of round section.

Another important type of frame is that consisting of a tubular " backbone " which may divide at the front end to form a U in which the power unit is located. It obviously possesses great resistance to lozenging, and, if correctly designed, also to twisting and to bending. If the front end is at all weak, however, local twisting may occur, but in this connection it must be remembered that this type of frame is frequently employed with separately-sprung wheels. The backbone need not actually be tubular, but may be a built-up box section.

From the foregoing it will be realised that what designers are aiming at is a frame which will not readily distort. A frame which can bend and twist may impair road-holding, and it can give rise to much trouble with the coachwork, for if the frame distorts it must obviously cause the body to twist and bend as well. The results of the body being forced to twist and bend may be merely annoying, such as the setting up of squeaks and rattles, or they may be more serious, such as fractured body frame members and cracked panels.

The box section frame member has much greater resistance to twisting than has a channel section member, and it is for this reason that the box section frame has received so much attention, and has become almost universal in modern design.

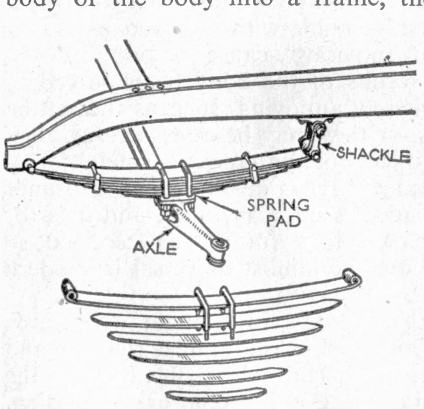
There are, however, two schools of thought as regards frame design, one striving to obtain the utmost rigidity, and the other maintaining that a slight degree of flexibility in the frame is an advantage in giving more comfortable riding. Those who maintain that the rigid frame is correct try to obtain even greater strength and rigidity in the complete

vehicle by attaching a steel body rigidly to the chassis, and since an all-steel body is itself really a box-section structure it is obvious that their efforts in this direction must meet with a considerable amount of success.

On the other hand, those who retain a slight flexibility in the frame endeavour to prevent it having any effect on the coachwork by embodying a degree of flexibility in the actual body mountings.

Which of the two is right? That is difficult to answer, but it would appear that the rigid frame and body, in conjunction with separately-sprung wheels, ought to be the logical development. Indeed, the tendency already mentioned to combine frame and body shell, which has spread from the Continent to this country, seems to support this view; but it has, of course, the disadvantage of restricting body design, so that probably there will always exist chassis of more or less orthodox construction on which individual coachwork may be built.

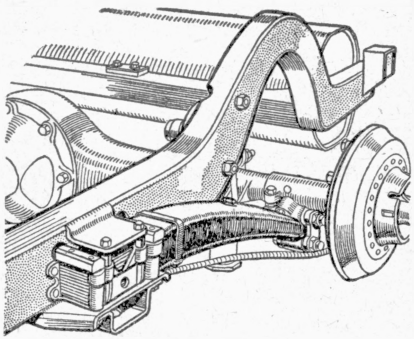
It will be seen that the frame has become a very complicated girder structure. There is now a tendency for it to disappear altogether, paradoxical as that may sound. But the normal car of to-day carries a saloon body and, when you come to think of it, the saloon body is an ideal metal box-section girder, can in fact be extremely strong. So we find that there is a gradual evolution of the frame into the body or the body into a frame, the body being made just sufficiently stronger to serve the purpose of the frame, and the machinery — that is, engine, gear box and axle — being attached as separate units. The metal used may be steel or light alloy, but the principle is the same and the idea will probably develop as time goes on.



Composition and mounting of an orthodox half-elliptic road spring. The top leaf has shackle eyes formed in its ends

Even at the present moment the body of a car with a frame is such an important

girder that the normal frame may have to be stiffened if an open instead of a closed body has to be provided.



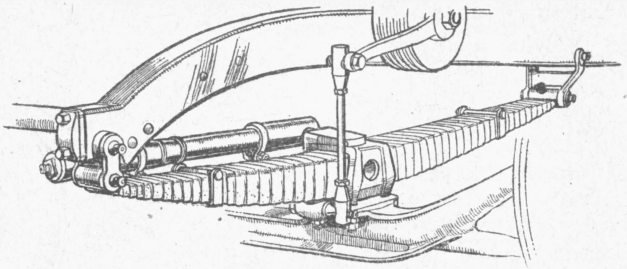
So-called quarter-elliptic rear spring, really a true cantilever but never so described; a gaiter here encloses the leaves

Most vehicle springs are laminated, that is, they are an assembly of steel strips, or leaves, of gradually decreasing length. The top strip, or master leaf, has the ends rolled over to form an eye, one eye being pivoted to the dumb iron or frame bracket forked to receive it, while the other eye is connected to a further bracket by a link or shackle. The purpose of the shackle is to allow for the increase or decrease of the length of the spring as the axle rises over a bump or sinks into a pothole.

Over the thick centre portion of the spring pass two U bolts or a clamping plate which hold the spring firmly to a flat platform or spring pad formed either over or under the axle. Usually the spring rests on the top of the front axle, but generally it is attached beneath the rear axle, in this case being described as underslung.

On a few cars quarter-elliptic springs are used, and these may be considered as half-elliptic springs cut through the thick centre portion. They are attached to the frame by clamping the thick ends to suitable brackets, and the projecting thin ends are then bolted to the axles, the springs being upside down as compared with the half-elliptics. When such springs are used there is no need for dumb irons or shackles, and so the frame design is modified.

Another suspension system popular with some manufacturers is that using transverse springs. In this case it is usual, in order positively to locate the axles, to fit a triangular structure of radius rods ; the springs are inverted half-elliptics and are shackled at each end. They may also be low-hung in a position before or behind instead of being directly above the axles, as in the 10-h.p. Ford, in order to reduce the overall height.



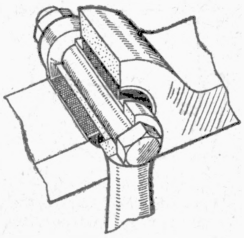
Front spring shackled at each end, the axle being located by means of a massive radius rod alongside each spring, which also resists the torque of the brakes

The cantilever spring, now little used, is an inverted ha elliptic parallel with the frame, pivoted by a trunnion brac at its centre and shackled to the frame at the end remote fr the axle. The other end is fixed to the axle, either rigi or with the shackle or slide, according to the method adopt to take the drive thrust.

There are various methods of attaching the springs to t frame. The spring end can have a bearing working abo a pin, the longest or master leaf being coiled round at the e to form an eye to embrace the pin. Often the second longe leaf is also coiled half round the pin to provide addition security. Alternatively, the spring may be " shackled ", th is to say a shackle pin is passed through the eye of the mast leaf and is connected to the frame by means of a link, whi itself has a second shackle pin swinging in a bearing brack on the frame. Another form of attachment consists of slotted cylinder swivelling in a housing, with the end of th spring sliding in the slot.

On most popular cars of to-day the bronzed bushed eye o the spring working on the shackle pin has completely dis appeared in favour of the compressed rubber bush, thereb eliminating a source of squeaks and removing from the chassi about a dozen points that called for regular attention wit the grease gun. The pioneer type was the Silentbloc, which is a short length of rubber tube compressed into a light steel shell and having also a steel tube through its central hole. The rubber is firmly secured to these steel tubes and is pressed into the shackle bracket or spring eye as a complete unit. When the shackle bolt is tightened to grip the central tube,

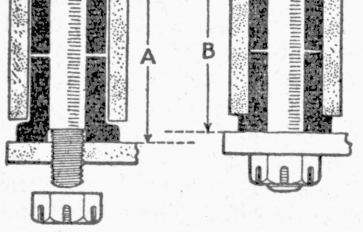
oscillating movement between the spring and the bracket is entirely accommodated by the torsional elasticity of the rubber. No lubrication is required and the life is very extensive without attention. Latterly a new type of rubber bushing has arrived from America. This is the Harrisflex. It is not pre-compressed between two light steel tubes, but is inserted loosely into the eye or bracket and *then* compressed to grip the opposing surfaces by tightening up the shackle pin to a predetermined pressure set by the design of the parts. Its advantage is particularly that it can be assembled without a special press ; moreover it is not damaged by a temporary overload.



A Silentbloc shackle bearing

Interest in independent suspension was evident on the Continent and in America for a considerable time before it was adopted by certain manufacturers in this country. Even so it had only a limited popularity up to 1939, although Rolls-Royce, Lagonda, Humber, Hillman, Alvis, Vauxhall and Standard, in fact, adopted it.

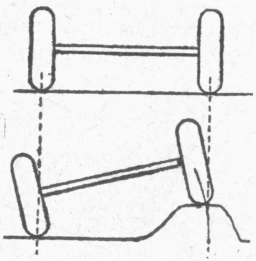
In reviewing independent suspension, however, it is necessary to adopt some simple form of classification in order to avoid confusion, for at first sight two systems may seem to be radically different—one, for example, may utilise coil or leaf springs, whereas another may utilise torsion rods—although actually in principle they may really be of the same basic type. In short, confusion is best avoided by separating the means of suspension *per se* from the actual mechanical method of attaching the wheels to the chassis, the classification being made according to the latter factor.



The Harrisflex rubber bush is easily assembled without special tools. (A) Assembled (B) Tightened

In the first place, consider the normal arrangement of solid axle beam, each end of which carries a wheel, the suspension being by two half-elliptic springs, one between each end of the axle beam and

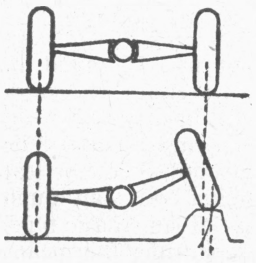
the chassis. The fault of such a system from the suspen point of view is that when one wheel encounters an obsta and is forced to rise, the axle beam is tilted and with it other wheel, the whole system pivoting, as it were, about point of contact of the second wheel and the road.



Effect of solid axle on meeting a road obstruction

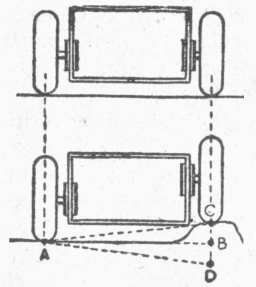
The angular displacement of axle beam inevitably means that only is the spring nearest the ris wheel compressed, but also the ot spring, although to a lesser degr so affecting riding comfort m than if only the one wheel a spring were concerned. Mechanica of course, the springs are not o deflected but they must accommod the unequal movement by twistin

This fact was early realised by t designers of both the Sizaire a Lancia cars, who, to overcome arranged that each front wheel shou be free to move in a vertical directi without affecting its fellow. Th system was applied to the fro wheels only, as when the drivin wheels are to be independently sprun other problems are introduced arranging for the drive to t transmitted.

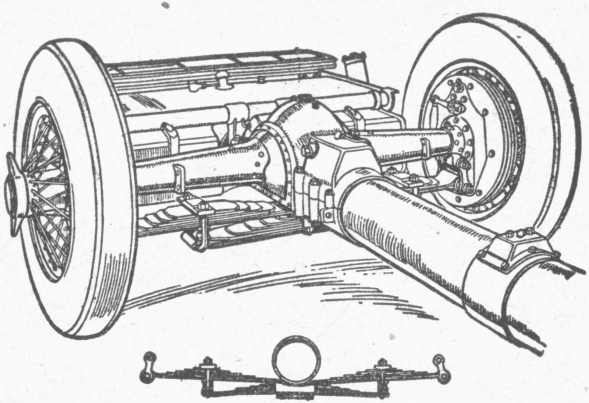


Principle of swinging half-axles

An early solution of these problen was, however, provided by Austr Daimler, which introduced anothe type of independent action. In th the final drive unit is a part of th chassis, and each half-axle is pivote to the differential casing. As a whee encounters an obstacle it swings i an arc of a circle, the centre of whic is the final drive, so that the track is for the time being, increased by th action of the wheel. Similarly, shoul one wheel descend into a hollow such as a pothole, the track will b decreased a little.



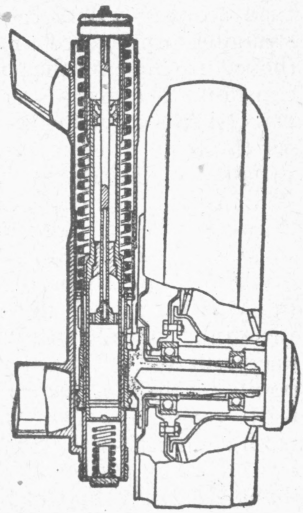
Independent suspension by vertical movement



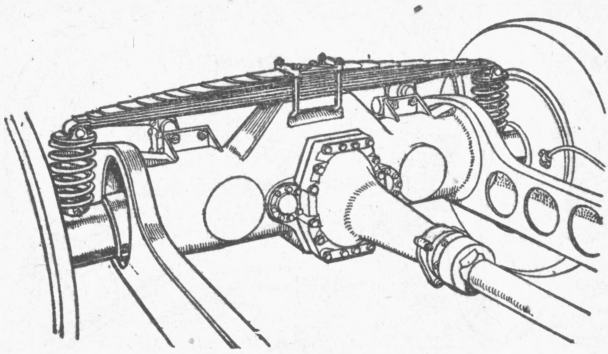
The swinging half-axle system applied to an Austro-Daimler using a unique arrangement of transverse cantilever springs

Next to be considered is what may be termed the parallelogram system. In this each stub axle assembly or steering head is carried by two parallel links, so that as the wheel rises it moves parallel to its original position.

If the parallel links are normally horizontal then any movement of the wheel must decrease the track, and the shorter the links the greater will be the variation involved. In some examples of the parallelogram system the links are necessarily somewhat short, and the resulting appreciable variation of track gives rise to tyre wear produced by the scrubbing action of the tyres on the road. To overcome this disadvantage the linkage is frequently laid out so as not to give a true parallel movement to the wheel. The lower link is made the longer of the two, the result being that as



Lancia type suspension which allows the wheel hub assembly to move vertically up and down on a tubular guide



Maybach swinging axle layout employing a transverse leaf and coil springs

the wheel rises its rake is altered. By careful layout of t linkage the alteration of the wheel rake may be made almc to eliminate the track variation and the scrubbing action.

In another system each wheel is carried on the end of swinging arm pivoted to the chassis and moving parallel wi the centre line of the chassis, and although track remai constant there is a variation of wheelbase. Perhaps tl greatest objection to this layout, however, is that when use for the front axle the resultant movement causes a continu variation of the trail of the steering pivot on which the nece sary castor action depends.

These wheel movements have been pointed out in th various systems because their effect not only on tyre wea but also on the steering has to be considered by the designe In systems such as the Lancia, in which there is no trac variation, the only steering problem is that as the wheels ris unequally there is slight variation in the distance between th points on the two steering heads to which the tie rod (or trac rod) joining the two hubs is attached. This variation i theoretical rather than practical and it can be taken care o by the spring-loaded ball joints, but in other systems wher the movement is greater it is necessary to use a divided track rod, or even to employ independent connections between th steering box and the front wheels.

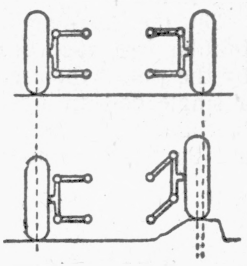
It is not proposed, however, to delve into such problems though it is well that they should be mentioned, so that th

iner points of the various systems may be appreciated. Four ystems have been defined, which are—

(1) Vertical (constant track) movement in guides;
(2) Swinging movement by pivoted half-axles ;
(3) Parallel or swinging movement by two links ;
(4) Constant track movement by pivoted arms swinging fore and aft.

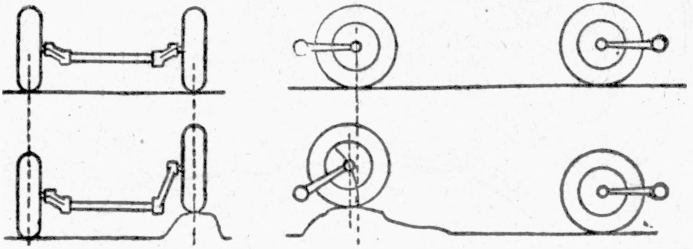
Sizaire conceived the idea of rigidly attaching the axle beam to the front of the chassis and allowing the wheels to move vertically in guides formed at each end of the axle, the actual suspension being by means of an inverted transverse half-elliptic spring rigidly attached at its centre to the chassis and with its ends attached to the upper extremities of the vertical sliding portion of each stub axle assembly.

In the Lancia design the action of the wheels is similar, but the axle beam is replaced by a tubular construction, in the vertical members of which the vertical part of the stub axle assembly, in other words the steering swivel, slides up and down as necessary. The leaf spring, however, is replaced by coil springs, which are also conveniently housed in the vertical tubes, the upper springs taking the weight of the car and the lower the recoil. Furthermore, within the coil spring a hydraulic shock absorber is easily incorporated.



The parallelogram system, showing how track width decreases when the wheels rise above normal

Of this type the Austro-Daimler was an early example, and it had, of



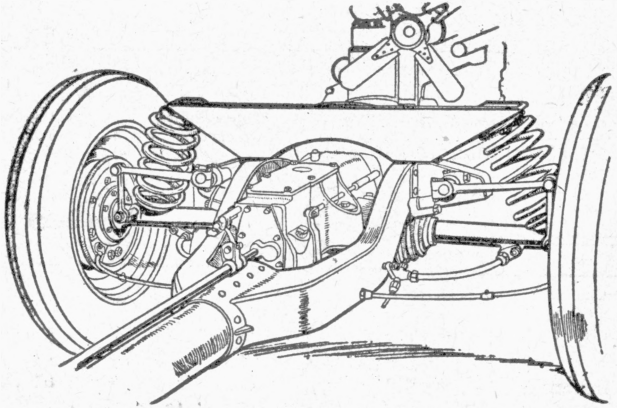
Swinging arm type, front and side views

course, the tubular backbone chassis construction which has since been adopted by other makers. The final drive unit is rigidly attached to the end of the tubular backbone, and the half-axle cases are pivoted to the final drive casing. The suspension makes use of three half-elliptic springs. The wheels rely for positioning solely on the rigidity of the half-axle cases and their pivoting to the final drive casing.

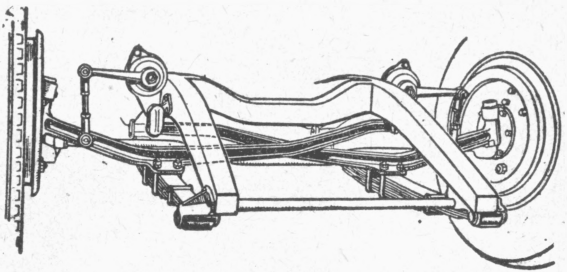
The rear axle of the Auto-Union is similarly arranged with swinging half-axle cases, and a transverse spring above them shackled at each end to the half-axle cases, while beneath them brackets project from the frame to carry the friction-type shock absorbers, the moving arms of which are linked to the half-axle cases.

The Mercedes-Benz type 290 and 500 have pivoted half-axle cases which are positioned by radius and torque members, while the suspension is by a pair of coil springs at each side interposed between brackets carried on the axle and the frame members. There is also a tension coil spring between levers depending from the pivot pins of the half-axle cases.

On the rear-engined Mercedes-Benz, model 130, with a tubular backbone chassis, the pivoted half-axles are located by the pivots themselves without the use of radius rods, and a single coil spring is interposed between the end of each half-axle case and a frame cross-member. When coil springs are used, as in these cases, it will be noticed that they are



Mercedes-Benz 130 with tubular chassis, coil springs and built-in shock absorbers



Ingenious system on the Unic using a separate axle beam for each front wheel

requently set at an angle, which minimises lateral disturbance of the spring due to the movement of the wheel in the arc of a circle.

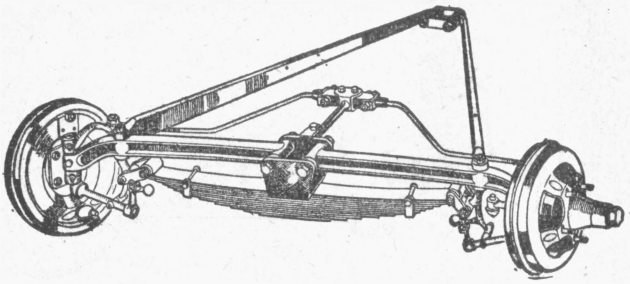
Quarter-elliptic springs are used for the rear suspension of the Steyr 100, the half-axle cases again being pivoted to the final drive casing on the chassis and located by the pivots. The springs are shackled to the half-axle cases and project forward from their butt ends, which are bolted to the chassis frame.

The Derby is interesting, as it applies the pivoted half-axle principle to both front and rear suspension, a transverse half-elliptic spring being used beneath the half-axles, to which each end of it is shackled. This is a front-wheel drive model.

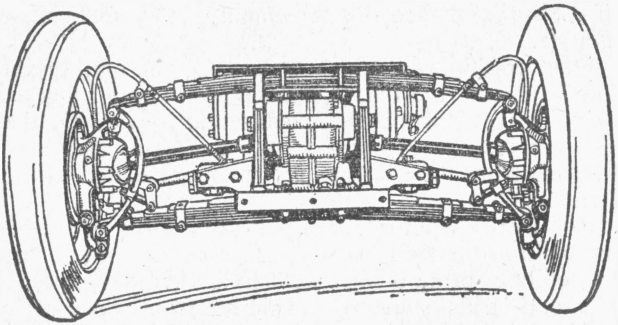
Another interesting example of this system is that used on the Mathis EMY6. In this, the rear half-axle cases are pivoted to the final drive unit, which is attached to the chassis, and the suspension is by torsion bars.

The splined rear end of the torsion bar engages with splines in the forward pivot of the half-axle. The forward end of the torsion bar is supported by a strong frame cross-member, and carries on splines a depending lever attached by a link to a bracket on the cross-member. This link is adjustable for length, so that the initial loading of the torsion bar can easily be adjusted.

There are two forms of front independent suspension which also really fall in this group. One is the Unic, which employs what may be termed pivoted " three-quarter-axle " beams. The steering heads and wheels are carried by what at first sight appear to be a conventional solid axle beam and half-elliptic springs, but actually each wheel has its own beam,



The Ballamy design for converting existing solid axles where a transverse spring is used—such as Ford and Austin Seven



A German layout, the D.K.W., using transverse half-elliptics

which extends only as far as the main frame member on the other side, to which it is pivoted. The movement of the wheels is, therefore, in the arc of a circle and the arrangement accordingly is included here. The wheels are located by the springs.

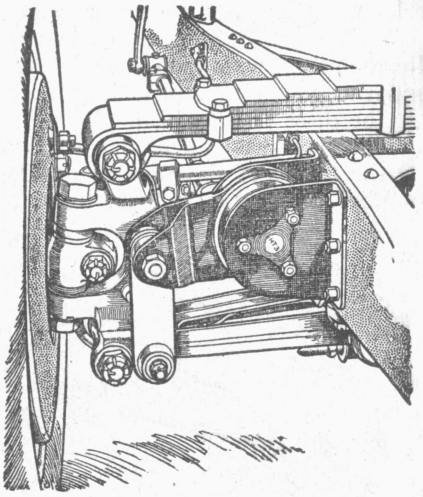
In the Ballamy design, which has been used for converting existing solid axles, the axle beam is divided at the centre and each half is hinged to a bracket carried by the chassis. Radius rods locate the wheels, and suspension is by a transverse half-elliptic spring shackled at each end to the half-axle beams.

It is recognised that no suspension system is perfect in itself. It cannot be, because the conditions demanded by comfortable riding at slow speeds over good roads in any car are utterly different from those involved when the same car is driven far and fast on a tour. It has therefore become

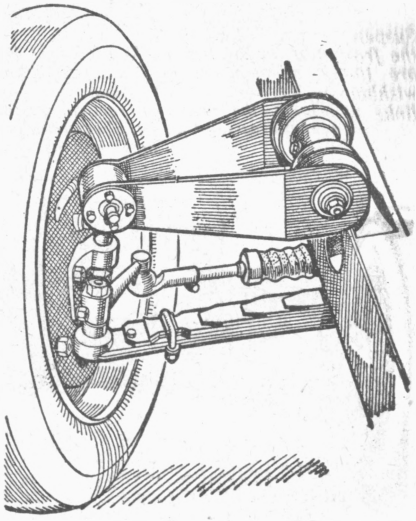
stomary to provide me additional con- ol by means of hat are called shock absorbers". Friction dampers id spring snubbers ere the first shock osorbers as far as ne can tell, though iere is an element of oubt as to whether n hydraulic shocker" did not un them a close econd.

Spring snubbers, vhich have now been superseded, consisted of a length of tough woven fabric held within a drum under spring tension: rather like the "self-return" type of tape measure. The drum was generally secured to the chassis, and the "tape" to the axle. The upward movement of the axle was unchecked but the return of the spring was resisted and so the rebound was slowed and smoothed out.

The earliest friction types were the Hartfords beloved of racing men: two arms, acting caliper-wise, one blade



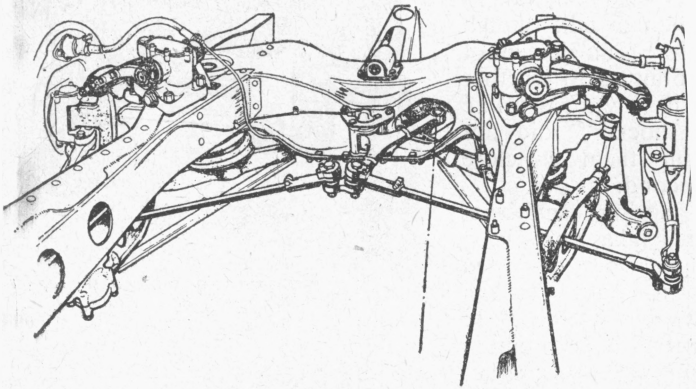
Alvis cars have a transverse spring at the top and a wishbone at the bottom



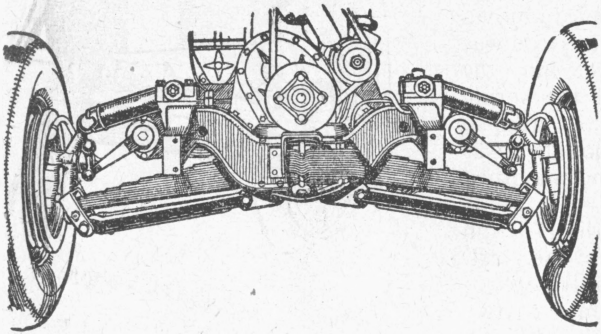
The Salmson is another design using a wishbone above a transverse spring

attached to the axle, the other to the frame. At the pivot w two or more hardwood discs threaded on a bolt passi through the overlapped ends of the arms. A slightly con star-shaped spring, adjusted by a large nut, enabled pressu on the discs to be varied.

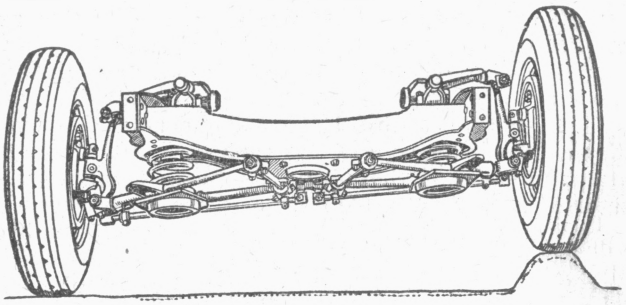
This system is still used, sometimes rendered more robu by the fitting of several intermeshing arms, and of course number of hardwood discs in place of two or three. Tl



Suspension of the latest Rolls-Royce Silve Wraith. Anchored to the centre o the front cross-member, the wishbones incline rearwardly and the extremitie are linked by longitudinal radius rods to the frame sides. The uppe wishbones form the arms of vertical piston type hydraulic dampers. Al links are made as long as possible to allow rubberised bushes to be use without incurring too much flexibility



On the Studebaker super-imposed links are used with a transverse spring lying between them

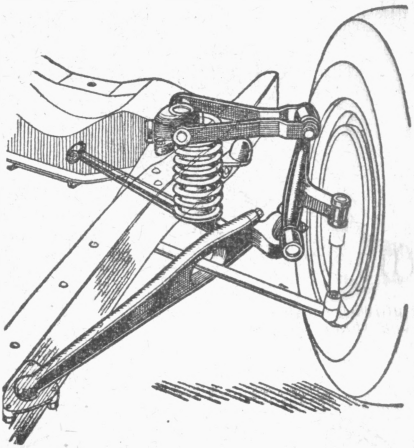


On the Oldsmobile the lower links are longer, and coil springs are used

result is a damping arrangement operative in both directions.

The second type of shock absorber depends upon oil hydraulic action and it has become almost universal on the popular type of car.

Several different designs and makes are produced, but in all cases the principle is similar. Movement of the axle is conveyed to a piston or paddle that fits closely in an oil-filled chamber. Taking the piston and cylinder as an example, if the cylinder is filled with oil the piston cannot rise, and so the axle connected to it is prevented from moving. But if in the cylinder or piston there is a leak hole (or valve) the piston can move by virtue of the oil leaking through, hence the movement of the axle can be controlled and the resistance of the spring suspension can be reinforced from zero to " solid " by adjusting the valve.



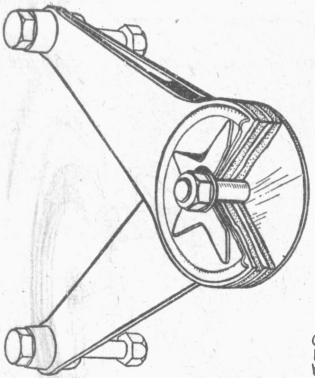
On the Packard the upper wishbone projects slightly forward, and hinged arms take the place of the lower wishbone

Sometimes the hydraulic shock absorber works equally in both directions, but it is obvious that two valves each capable

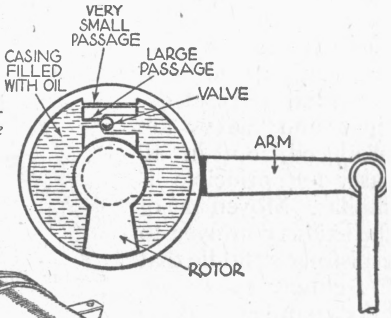
of passing oil only in opposing directions can be adju independently to check spring compression slightly expansion (or rebound) very strongly ; thus this type shock absorber can be set to suit various conditions.

Hydraulic shock absorbers, or dampers as they should called, especially those of the vane type, are apt to call attention which in the normal course of events they do receive, as they are usually in inaccessible positions. In most recent design, the Luvax-Girling piston type hydra damper, a special study been made of ensuring rel bility for long periods of u The special fluid is carefu sealed in, and the damper provided with a recuperati chamber from which the bo is kept filled.

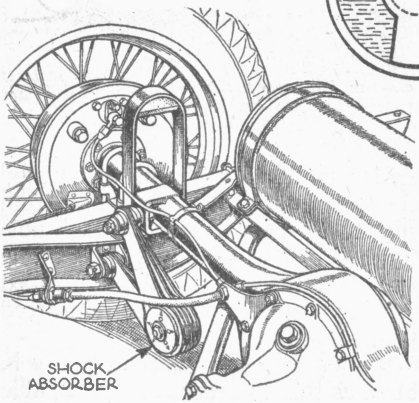
Control from the driving se is possible. One of the bes



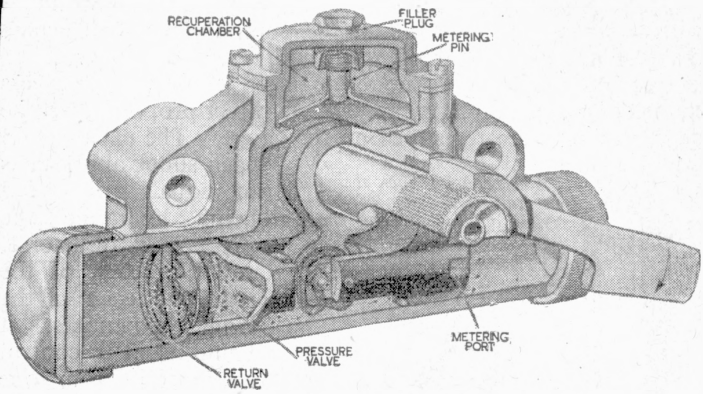
Cutaway view of a simple friction-type shock absorber, showing the friction discs



(*Above*) *The working arrangements of an hydraulic shock absorber*



(*Left*) *It is considered by some that a better anti-rolling effect is produced by mounting the absorber transversely, as here*



Minimum adjustment and replenishment are required by the latest Luvax-Girling piston type hydraulic damper, which has a recuperation chamber to maintain the fluid level

known schemes is the André Telecontrol system, which combines a multiple-disc friction shock absorber of the Hartford type with hydraulic control from the driving seat. The principle is essentially simple : there is a friction type absorber and a hydraulic operating unit. These two assemblies are self-contained and are interconnected by means of a central bolt to form the complete shock absorber.

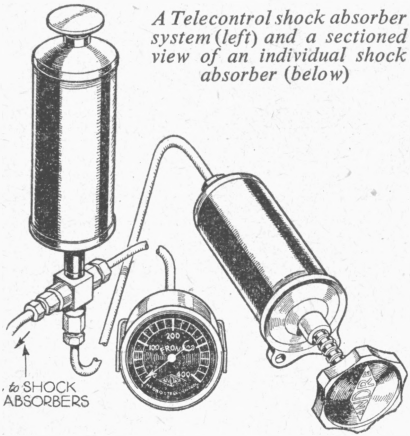
The shock absorber arms are faced with non-corrosive friction plates between which specially treated friction elements, conical in shape like the ends of the arms, effect the necessary damping resistance. The whole assembly is sealed so that neither moisture, dust nor dirt can enter it.

The operating unit in the shock absorber consists of a rubber expander with internal channels for the hydraulic fluid, and this expander is enclosed in a metal container and held in position by a central bolt connecting with end plates on each side of the absorber. The regulator, which is fitted to the instrument board, consists of a cylindrical casing in which moves a flexible container holding the operating fluid.

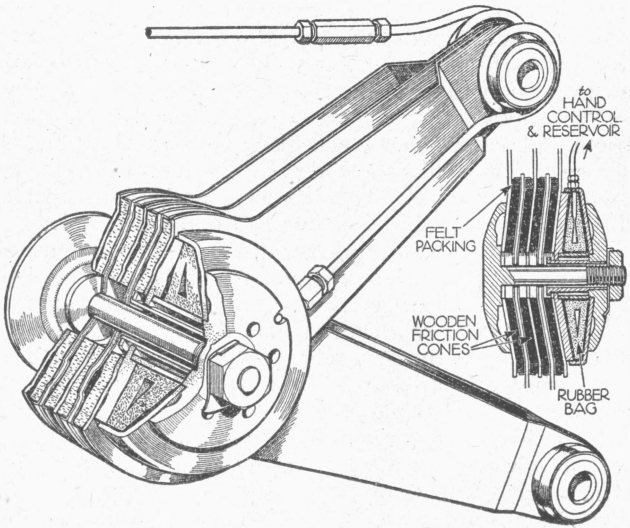
There is a hand control wheel by means of which a plunger can be screwed down, thus setting up a pressure in the container which is transferred through pipes to the absorber. A pressure gauge gives the exact degree of adjustment.

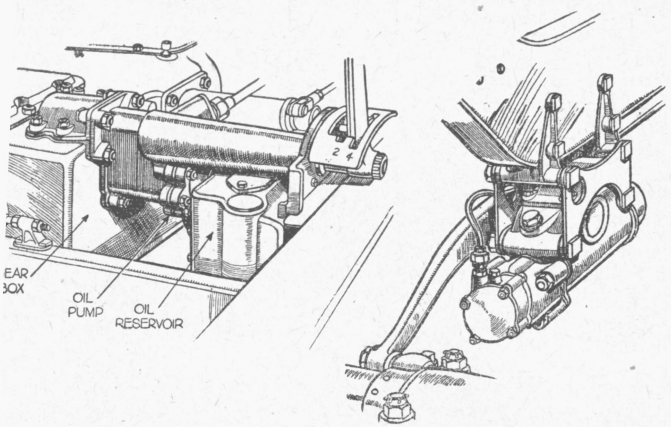
A reservoir and filling pump for each "circuit" is fitted with a non-return valve and a hand pump, by means of which the system can be charged with fluid when necessary.

As pressure is imposed upon the liquid within the expanders the friction assembly is compressed in direct proportion to the degree of pressure registered on the gauge. The expander in each shock absorber is of equal area, and being hydraulic the pressure is, of course, equal in each of the rear and each of the front expanders, it being usual to control each pair from one regulator; the result, therefore, is bound to be absolutely balanced damping to each pair of wheels.



A Telecontrol shock absorber system (left) and a sectioned view of an individual shock absorber (below)



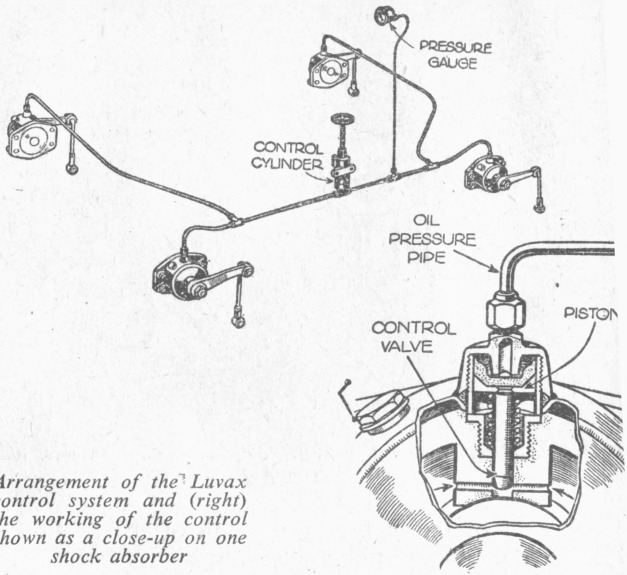


he pump and reservoir of the Rolls-Royce and Bentley shock absorber system, and (right) one of the absorbers

The object of the conical formation of the friction parts first to make the assembly automatically self-centring, and :ond to increase the friction surface. The arms of the ›sorber are fitted with the well-known " Silentbloc " bearings. Rolls-Royce and Bentley cars have hydraulic shock absor-:rs with a finger-tip control on the steering wheel. This 'stem is particularly interesting, as it indroduces an auto-atic control which is proportionate to the speed of the car, hile the small lever on the steering wheel allows an additional egree of control to be obtained at will.

This is accomplished in quite a simple manner, for on the de of the gear box there is an oil container and an oil pump. 'ressure is carried through pipes to each of the shock absor-ers, where it takes effect upon diaphragms which control the y-pass valves of the shock absorbers. The small hand lever s connected to a by-pass valve in the oil-pump circuit.

The action of the system is as follows : As the road speed of the car increases so does the speed of operation of the oil ›ump, since it is driven off the gear box, and so, therefore, loes the oil pressure developed, with the result that the by-›ass valves of the shock absorbers are actuated progressively o increase the damping action. The effect of the hand :ontrol is, as it were, to move the range of action of the ıutomatic control higher up the scale.



Arrangement of the Luvax control system and (right) the working of the control shown as a close-up on one shock absorber

On the road, therefore, the hand control will, for town us probably be set in the minimum position, and as the roa speed increases as the car gets clear of the town, so automat cally the damping action is increased.

Suppose, however, that a stretch of bad road surface then encountered, or the driver desires to travel at a sti higher speed, then by moving the small control lever on th steering wheel over towards the maximum position th damping action will be further increased. In fact, the drive can obtain the most satisfactory setting to cope with change of speed or variations in road surface merely by moving thi small lever with the finger-tips, and the response to the contro is, moreover, instantaneous, so that, for example, should a bac bump be suddenly seen, the control can be flicked over to the maximum damping effect.

In the Luvax hydraulic control system a control cylinde with a hand wheel on the end of the threaded rod is mountec in a convenient position for operation by the driver. Wher the hand wheel is turned it displaces fluid from the contro cylinder, and, therefore, a pressure is set up in the system o pipes which runs from the other end of the cylinder to the

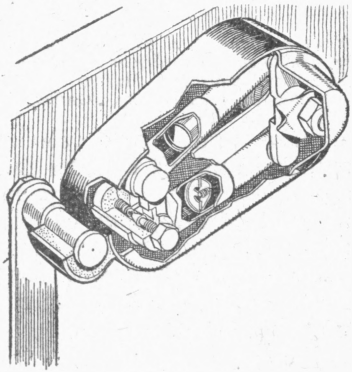
shock absorbers. A pressure gauge on the instrument board shows the pressure set up in the system. The two pipes from the control cylinder each branch out so that one pipe is connected to the front two shock absorbers, and the other pipe to the rear two shock absorbers. If desired two control cylinders may be used, one to govern the front and the other the rear shock absorbers.

The actual control is by means of a small cylinder and piston, the piston being carried by the top of the control valve, which in this case has a sliding action. A small coil spring round the control valve tends to keep the valve in the upward position, when it offers least obstruction to the fluid passing through the transfer passage in the shock absorber itself. As the hand wheel of the control cylinder is turned and pressure is set up, it is transferred through the pipe-line and so forces the piston down against the action of the spring, so progressively obstructing the transfer passage as the pressure is increased. It should be noted that there is no actual connection between the fluid in the control system and the fluid in the shock absorber.

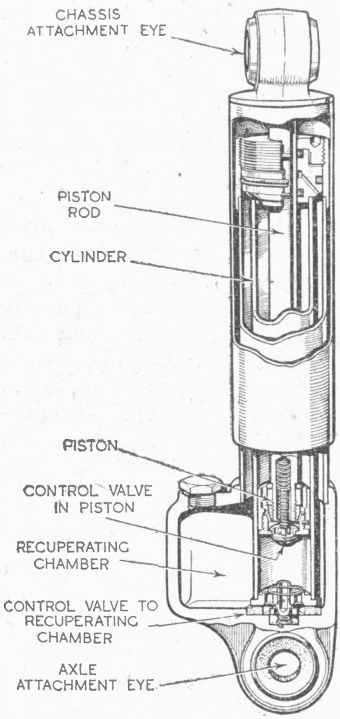
For the very latest cars it is true to say that the hydraulic shock absorber holds the field, and it is rare indeed to see the friction-type on a chassis. Apart from those hydraulic shock absorbers already described, there are two others which are becoming popular.

Of these, one is the Armstrong, which consists of two cylinders, each with its own piston working against oil and double-acting, that is, operating in both directions, the whole being enclosed in a casing which is linked to the moving axle and pivoted on the frame.

The second type of shock absorber is the Newton, which was used with great effect for the suspension of tanks and which, incidentally, in many ways resembles the shock absorber



Armstrong shock absorber in section, showing the arrangement of the two cylinders and pistons



Newton Bennett shock absorber in section to show the various parts which form the actual shock absorber, control valve and recuperating chamber

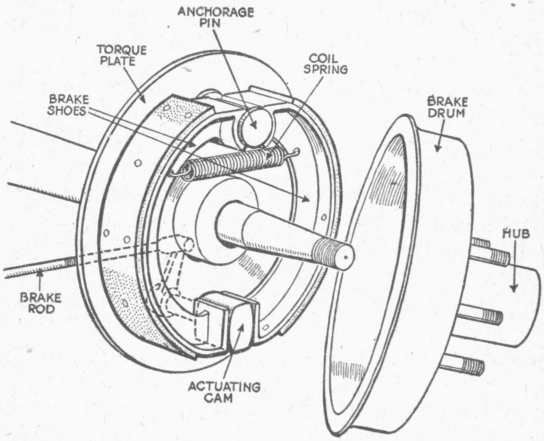
named a buffer, which has been fitted to guns for very many years. As the illustration alongside shows this shock absorber consists of a cylinder which is attached to the axle or wheel assembly, and in this cylinder a piston with a rod which in turn is pivoted on a bracket, held to the frame. The cylinder is full of oil. Upward movement of the wheel assembly naturally tries to force this oil past the piston, which is held stationary. The piston is therefore provided with disc valves which allow the oil to pass freely from one side of the piston to the other. On the rebound stroke, when the wheel assembly is falling, the oil has to return, but can only do so comparatively slowly, because the disc valve reduces the aperture through which this oil flows, the adjustment being set to suit circumstances.

There is, incidentally, another spring-loaded valve in the cylinder, which allows oil to pass from the cylinder into a separate chamber and to return therefrom when required. The shock absorber can be adjusted to operate by imposing either a resistance to the rebound action only or a resistance on both the upward movement and the downward movement of the wheel assembly. Furthermore, the damping effect can be controlled through very fine limits.

Brakes and Steering

AS is not unnatural, the brake system of a car has developed until the brakes of to-day are not in any way similar to ıose considered sufficient for the earliest cars of all. The roblem is, and always has been, interesting and complicated, aining in importance because safety depends on the absolute eliability of the brake mechanism, whatever the circumstances, /hatever the weather or the state of the roads. To-day all ars have brakes operating on both front and rear wheels, and he gain in braking power alone has been enormous, as was nevitable, considering the ever-increasing speed and weight ɔf the cars and the great density of modern traffic on most ɔf our roads.

The problem is this : A car must be capable of being stopped suddenly, quite surely and within a short space, whatever its speed, which means that when the driver presses the pedal the stopping power of all four brakes must be even, all interference with the steering being avoided, and that



An internal-expanding mechanical brake with the drum removed to show the parts. Note particularly the (dotted) position of the cam lever ; leverage is lost as soon as it passes " over centre "

power should be so set that the car will not skid violen even on a slippery road in wet weather. Consequently brak have become more and more complicated.

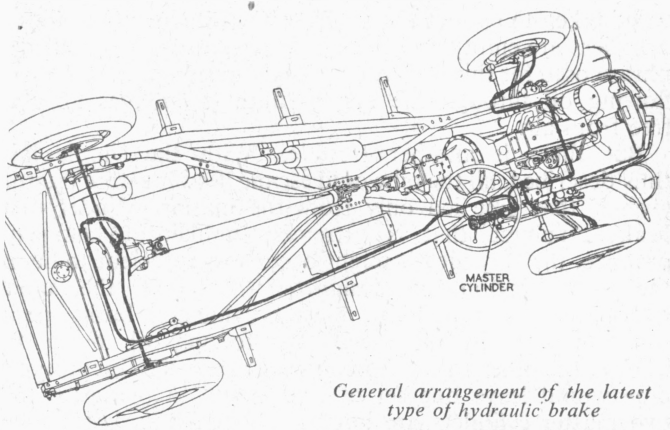
The original design consisted of a brake drum on ea wheel, a pair of shoes in each drum and a selection of ro and levers transmitting the push on the brake pedal to a ca which, forcing the brake shoes apart, made them contact tl drum. As the surface of the shoe was obviously the pa which would wear most, special linings of fabric were secure to the shoe face by rivets, the rivets' heads being sunk belo the surface of the lining so that they did not come in conta with the drum.

In this crude but simple arrangement the two shoes of eac drum were held on a pivot at one end, while the cam reste between the opposite ends, and the shoes were normally kep against the cam by coil springs. The drums had to be stif enough to remain round, whatever the force applied to them through the brake shoe, whatever heat was generated during the braking process.

That in itself was none too easy. That part of the brake assembly which held the brake shoes by means of the pivot had to be rigid enough to stop the brake shoes being dragged round by the revolving drum ; and to complicate the matter the cam had to be operated with equal power, whatever angle the front wheels and their drums took when the car was being steered round a corner. This problem again was not easy to solve, and the angle of movement of the front wheels was limited by the brake mechanism when first four-wheel brakes came into being. Both front and back brakes would move up and down with the wheels against the car's springs, a movement that had to be allowed without affecting the mechanism which applied the brake shoes.

It soon proved that this system was not efficient. One brake-shoe lining might wear a little more or less than another, yet the pressure on all the shoes had to be even. In practice the brake pedal rotated a tube held across the frame and the tube moved levers which exerted a pull on the rods connected to further levers turning the cam. Adjustment was provided by a handwheel or nut which could lengthen or shorten the rods, but this soon proved to be ineffective. From that simple beginning we have come to the far more reliable, much more complicated system used to-day.

One example is the hydraulic brake. Taking the Lockheed



General arrangement of the latest type of hydraulic brake

a sample, pressure on the brake pedal moves a piston in :ylinder which is full of oil. (Hydraulic, by the way, does t mean water only, but any liquid.) The oil in the cylinder therefore forced out along pipes which lead to small cylinders rried on the wheel assemblies as part of the brake mecha- sm. Each of these small cylinders contains two pistons, and ıen the oil is forced into the cylinder, these small pistons move ıtwards. As the pistons are connected to the brake shoes, ch of which has an anchorage pin as shown in the illustration age 175), the shoes move outwards with the pivot pin at the ntre, and so come into contact with the brake drums. Thus ranged, the pressure developed at the pedal is evenly trans- ıitted to the shoes in all four brake drums simultaneously. /hen the driver releases the pedal, coil springs bring the rake shoes back to their original position, the pistons in all ıe brake cylinders and in the main cylinder return also, and ıe wheels are free.

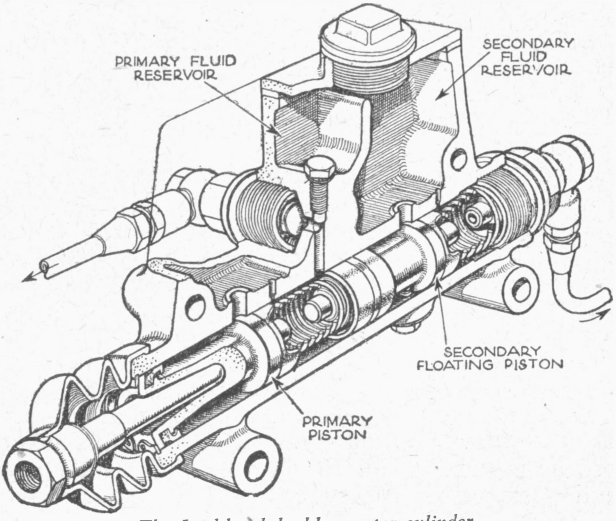
Now it is obvious at once that air must not mingle with ıe oil in any of the pipes or cylinders, because if you put ressure on a liquid it cannot be compressed, but if there is ny air in the liquid the air compresses, which reduces the nal pressure available to operate the brake shoe. Conse- uently there is a reservoir full of spare oil which is so onnected to the master cylinder that when the piston is perated by the pedal it will automatically replace any oil ıat happens to be lost. None the less, very great care has

to be taken to extract the air from the oil when the pipes cylinders are empty and the whole system has to be filled, phrase used for this operation being " bleeding ", which me flowing oil through the system until it emerges absolu free from air.

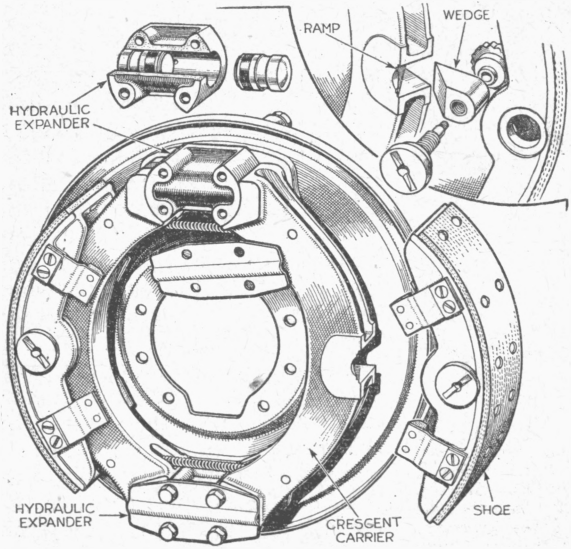
But there is another trouble. With the simple lay thus described, all the oil would escape if a pipe were fractu even if that pipe led only from the master cylinder to brake. Though that is extremely unlikely to happen practice, the very idea it might occur was sufficient to dema the consideration of designers. Therefore the mod hydraulic system has two master cylinders, both opera simultaneously by the pedal, one forcing oil to the fr brakes, the other to the rear, in which case the fracture of c pipe would leave one set of brakes still in operation. T two master cylinders are not usually separate, but are co bined in a casing with two oil reservoirs. Oil, by the w does not mean any oil, because it is necessary to have rubb or similar synthetic rubber cups on the various pisto rather similar to the leather cup in a bicycle pump and servi the same purpose, to seal the cylinder like a piston rin Therefore the oil used has to be of a type that will not cau the rubber or the synthetic rubber to deteriorate rapidly, a it is worth remembering that the oil which serves for re rubber is not the best for synthetic rubber.

It can be seen that this hydraulic system overcomes number of difficulties. The main pipes are of course secure to the frame of the car, but flexible pipes can lead from the to the brakes, and that allows for all the movements th wheel assembly may make when the car is travelling, a thin which otherwise would necessitate very careful arrangemer of rods and levers. Moreover, no rod-and-lever system i necessary for compensation, that is, for ensuring that all th brakes receive equal pressure.

Now there is another thing to consider. When the brake are applied to a car, the weight is thrown forward, whic means that for the moment there is more pressure, due t this weight, on the front wheels than there is on the back This in turn means that it would be more difficult to stop th front wheels, which might therefore slide along the ground than it is the rear wheels, from which the weight has tempo rarily been reduced. Consequently larger brake drums an shoes should be used for the front wheels than for the rear



The Lockheed double master cylinder

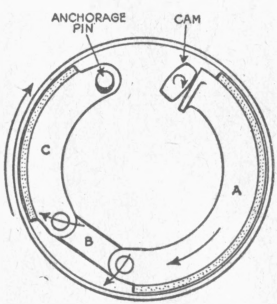


One type of Lockheed brake, showing the attachment of the shoes and the wedge which serves as an adjustment

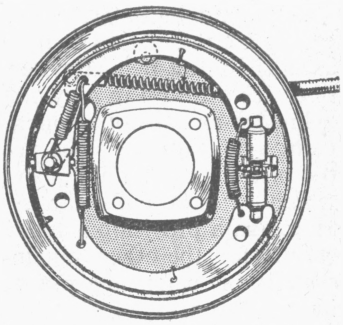
unless it is a matter of economy to make all four brakes as nearly identical as possible. Remember that the best braking effect is obtained just before the wheels lock. You actually lose stopping power when the wheel locks and slides.

But there are other little complications which should be considered in detail. If you imagine the brake drum revolving fast, you can see quite easily that the moment the brake shoe touches that drum, there is a tendency for it to be dragged round with the drum, just as will happen if you put your hand on the revolving drum. If then you study the drawing of a brake drum and its shoe, you will see that this braking action does not affect each shoe equally. In the rough diagram of a simple hydraulic system, each shoe rocks on a pivot at its lower end, but is moved outwards at the upper end by the piston. Assuming the near brake drums to be rotating anti-clockwise, the moment the left-hand shoe touches, the drum will try and drag it round, and in doing so will put it on harder, whereas the effect on the right-hand shoe is to try and push the shoe away from the drum. Because of the direction in which the car is travelling, the left-hand shoe is called a leading shoe, that on the right a trailing shoe, and it was soon found that the leading shoe wore its lining much faster than the trailing shoe, and was obviously doing all the work.

Consequently the modern idea is to make both shoes "leading shoes", which is done by having a brake-operating piston and cylinder at each end of the brake shoes and allowing the shoes a certain slight movement with the drum. The effect of this is exactly as though the true leading shoe was pivoted at the bottom, while the trailing shoe was pivoted at the top, the action of the rotating brake drum tending to apply both shoes equally. The other advantage which caused the shoes to be operated at both ends by pistons and cylinders was that a brake obviously has to be as effective when the car is going backward as it is when it is going forward, a difficulty that is met by this modification.



Principle of a self-energising brake. The cam operates shoe A directly, and shoe C indirectly through the link (B). Since C is anchored at the pin the rotation of the brake drum also tends to force the shoes into closer contact with the drum (as shown by the arrows)



The early pattern Bendix two-shoe self-wrapping brake. The cam is between the shoes on the left the adjustment on the right.

Now comes the question of adjustment. In the earliest brake gear, lengthening or shortening the rods sufficed, but as that cannot be done with the hydraulic mechanism, something has to be provided which will move the shoe nearer to the drum as the shoe lining is reduced by wear and so in effect keep the brake shoe at a certain set distance all the time. With hydraulically-operated brake shoes this is done by placing the lining on a small shoe which in turn is operated by a crescent-shaped carrier, one end of the carrier being operated by the hydraulic piston, the other end by another hydraulic piston, or held by an axis pin. Thus arranged, the shoe can be mounted on a wedge which can be made to move by means of a screw up or down another wedge on the carrier, and so bring the lining closer to or further from the brake drum.

The shoe cannot leave the carrier because of its shape and of certain guides that are introduced, and for the same reason it cannot move with the brake drum relative to the carrier. As the screw head projects at the back of the brake the screw can be turned with a spanner and is also arranged to lock automatically in any given position and to emit a clicking noise while it is being turned as a guide to those who are adjusting the brakes.

Remains the question of an alternative brake, as required by law, which is arranged by providing a lever within the driver's reach which pulls a cable which in turn expands the shoes in the rear drum. The purpose of this brake really is to hold the car stationary, as for example on a slope. It is not regarded nowadays as a really serious brake for use if everything else fails. Furthermore the brake lever, as such, is disappearing, its place being taken by a handle projecting from the instrument board though the work it does is the same and the handle is always provided with some form of lock to hold it in position when the brake shoes are applied.

A second brake system which is found on many modern cars is a combination of mechanical with hydraulic operation, as in the latest Bendix system. In this, pressure on the pedal operates a piston in a cylinder which in turn forces oil to the cylinders and pistons which actuate the brake shoes for the front axle, but that same pedal pressure, transmitted through the piston and its fluid, also tends to exert pressure on a lever which in turn pulls cables which operate the rear brakes. Here again provision is made so that in case one set of brakes should fail the other remains in operation, and a mechanical system of balancing pressure between the rear brakes is incorporated.

Another arrangement of brake shoes gives the two-leading-shoe effect which has been described already.

Then a third system is used in the latest Girling design, which has some very interesting points. In this brake mechanism, the driver presses a disc on the end of a rod directly connected to the piston in a cylinder, and this pressure drives the oil through pipes to actuate brake shoes in all four drums. Incidentally, the piston and cylinder are not quite usual, for the piston does not touch the walls of the cylinder as is usual, but merely enters into a chamber full of oil, the natural effect being that oil is displaced and thus forced down the pipe.

But there is an even greater difference between this system and any other. The brake-shoe linings always touch the

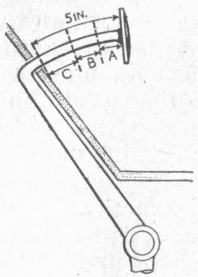
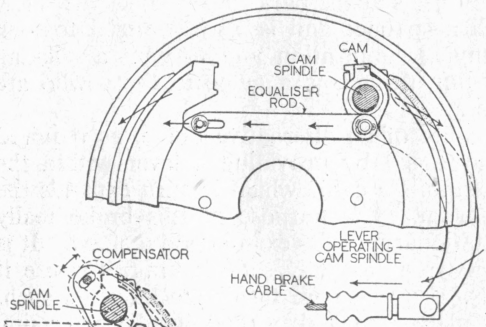
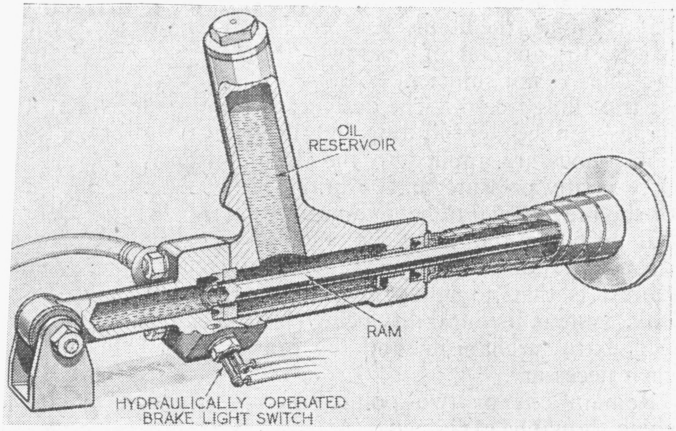


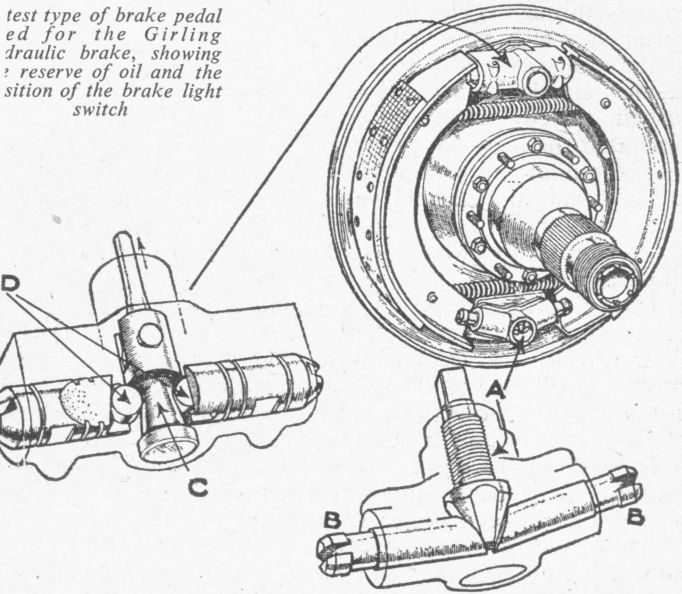
Illustration to show movement of the brake pedal in the latest Girling brake



Hand-brake connection for Girling brake with details of the compensator



test type of brake pedal ed for the Girling draulic brake, showing reserve of oil and the sition of the brake light switch



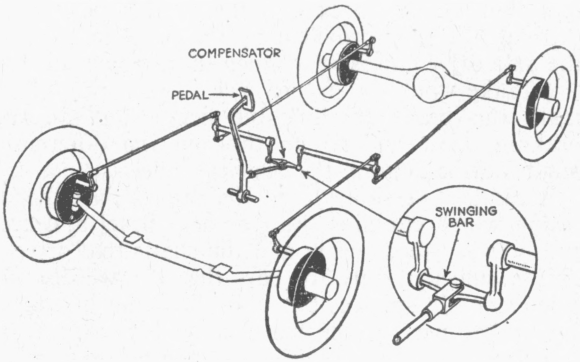
Girling brake arrangement; with details of the expanding plungers. A lifting effect is produced by setting the plungers at a slight angle to each other. This type is earlier than the hydraulic systems now used

A—Adjustment spindle
BB—Sliding plungers
C—Cone-shaped expander
D—Hard steel rollers

drum. Now this seems extraordinary, but it has been proved that as long as the linings rest very lightly against the revolving drums, the amount of wear which takes place is negligible, and there is not sufficient friction to be noticed or to stop the car travelling freely. The designers' claim, then, is that if the linings can be kept resting lightly against the brake shoes, those shoes are applied to the drum instantly, the moment there is any pressure on the brake pedal, whereas it is usual for the brake pedal to have to move forward a certain distance, thus bringing the shoes up against the drum, before any brake effect can be obtained. A further point of considerable interest is that no adjustment is incorporated at all in this brake system, its durability being claimed as sufficient to avoid such extra mechanism, and the brake lining being replaced when necessary.

Remain one or two points, mainly affecting older cars, which should be explained. At one time brakes were operated entirely through cables instead of rods. The original Girling design used rods, but the rods pulled wedges and the movement of the wedge expanded the brake shoes, which in many ways seemed simpler than connecting the rods to a lever which turned, thereby turning a shaft which moved the cam and separated the brake shoes. By the way, rods are in tension, that is, pulling, instead of pushing, because they can then be much thinner than would be essential to stand pushing, just as a bicycle wheel spoke can be very thin indeed to take its load, whereas the wooden-spoked cart wheel has very thick spokes.

The compensation system to equalise pressure on the four brakes in a mechanical system of operation of the early type, is shown in the accompanying diagram (page 185). The pedal, it will be noticed, is connected by a rod to a small horizontal lever sometimes called a swinging bar. Each end of this bar is in turn connected to a lever and thereby to the rods operating the brakes. As soon as one set of brake shoes touches its drum, it stops, but the pedal continues. That means that one end of the swinging bar is stationary, which being so, the other end levers forward the remaining brakes until they too touch their drums, and then all four take up the pressure. The action is, of course, instantaneous, though it sounds lengthy, and it was never particularly efficient. For one thing, a single swinging bar, as shown in the diagram, was not sufficient, for, in the form shown, it would only



Early type of compensation for mechanical brakes, to give equal effort fore and aft

sure that the off-side set of brakes were balanced against the ar-side set of brakes, and it proved necessary to introduce complete compensation system for the two front brakes, en for the two rear brakes and finally between the front and ar brakes, which meant a great number of small levers, ttle joints and trouble generally.

Remains to add that a great deal of development has vastly nproved the brake drum itself, for it has been proved that ertain metals make a better brake surface than others and lso are less liable to be damaged by the action of the brake hoe, which, curiously enough, has been known to cause rooves to be formed in the brake drum, although the lining s softer than the steel, and where the brake drum is made of light alloy, that is, what most people call aluminium, a steel or cast-iron brake surface has to be cast into the aluminium. Light alloy, by the way, is used because this materially gets id of heat very quickly in contrast to steel or cast iron, and t is highly essential to get rid of heat from the brakes, as otherwise the effect may be greatly to reduce the brake power as the drums become hot.

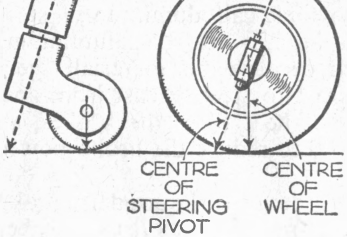
This is all the more important because the modern brake drum is almost sunk in the wheel and is not, as it used to be, in a position where it can receive easily the current of air caused by the movement of the car. At one time a brake drum with shoes was arranged behind the gear box and in front of the propeller shaft, in order to take advantage of the

fact that if you apply a brake in this position it oper through the gear provided by the bevel and crown whee the axle drive and is very much more powerful than a sim size brake would be on a wheel. But it was very difficul make this brake anything but fierce, and unfortunately braking effect had to go through the differential, and might not be even on the two rear wheels.

A modern version placed the brakes on either side of casing which contains the rear axle bevel and crown wh and between those gears and the shafts that drive the whe This is effective only for cars the rear wheels of which independently sprung, but it is the same in effect as hav the brakes part of the wheel assembly, except—and this all-important—that the weight of the brakes is not carried any part of the chassis which moves up and down with t springs, and to reduce the weight that makes this moveme is of importance.

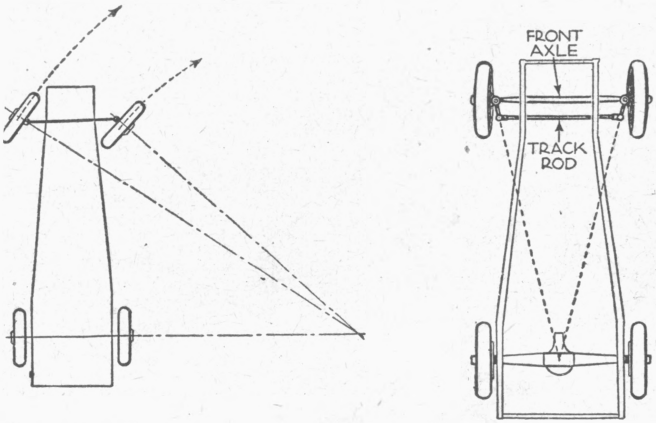
Turning now to the steering gear : there are three ba facts about steering, or perhaps principles would be a bett word. The first is that all steering systems to-day work the Ackermann system, and that practically every manufa turer arranges his steering to give caster, or self-centrin action to the front wheels. Facts two and three concern t two drag-link systems in use to-day, which may either t transverse or fore-and-aft.

The means by which the rotational movement of the steerin wheel is transformed into an oscillatory action are various some non-proprietary, othe the subject of patents an trade names. Of the firs kind, there are simpl arrangements such as worm and-wheel, worm-and-nut worm-and-sector, an epicyclic. In all cases th named mechanism is en closed within a housing known as the steering box.



"Caster action" depends upon a steering pivot in advance of the wheel axle to provide "trail". When this is impracticable the same effect is obtained by inclining the steering pivot

It was once thought that a steering gear should be completely irreversible, in other words that it should not be possible to

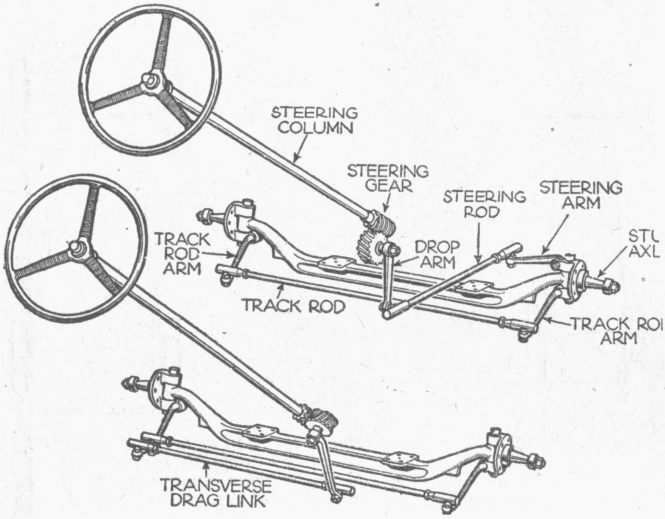


The essence of Ackermann steering : the radii of the paths followed by the two front wheels must as nearly as possible intersect at one point in the rear axle line, and the steering arms must lie along lines which meet at the centre of the rear axle

n the steering wheel by deflection of the road wheels. ı the face of things a car with irreversible steering should ntinue on the course set by the driver irrespective of road :qualities or roughness, but in actual fact the irreversible :ering mechanism not only refuses to be influenced by small ad deflections but equally it resists the self-centring influence the caster action layout, the upshot being that a car with versible steering, providing the caster effect is pronounced, ill hold its course over bumpy going much better than one ith irreversible steering.

A screw thread of fine pitch is quite irreversible, that is, ırning the screw will traverse the nut but no amount of ushing at the nut will turn the screw. Screws of coarse itch, worms and worm wheels, and the worm and sector vhich is merely a part of a worm wheel), are all partly rever- ible and the modern steering gear, by careful adjustment of aster action, trail and partial reversibility gives easy control, ppreciable self-centring effect, and minimum of reaction at he steering wheel to deflecting forces applied at the road urface.

The worm-and-nut scheme has a square-threaded screw on he steering column engaging with a nut which is so restrained



Fore-and-aft, and (below) transverse or side to side drag-link systems. Note that the terms "steering rod" and "drag link" are interchangeable

as to cause it to move up and down as the steering wheel turned. This is an admirable type of steering.

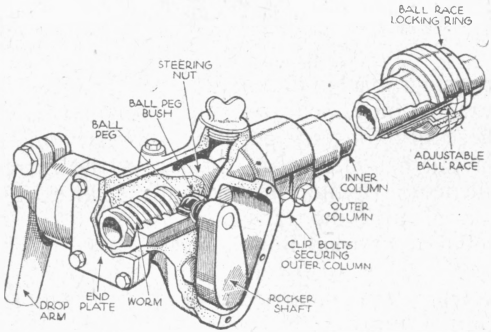
Epicyclic steering has in the past had a few adheren Then there is another type, in which a pinion on the end the steering shaft engages an internally-toothed ring.

Over and above these are various excellent proprieta systems such as the Burman-Douglas, the Marles-Weller a the Bishop, these being variations based on the worm, whi however, is usually of a specially waisted or "hour glass form. The engaging piece attached to the shaft of the dr arm is either a rotatable peg or a ball-bearing disc engagi with the worm groove. The shape and dimensions of t groove provide an automatic variation in gear ratio so th in the straight ahead position small movement of the steeri wheel produces a relatively considerable deflection of the ro wheels, but as full lock is approached the amount of steeri wheel rotation is increased in relation to the angular mov ment of the stub axles, and thus as the lock increases t steering ratio is lower ; this characteristic facilitates parkir Because of the frictionless construction these various "ca

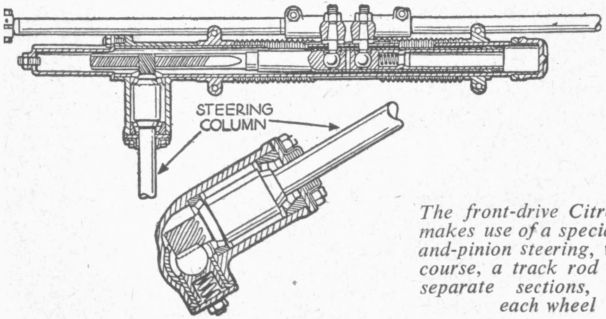
oller " steering gears have a high degree of reversibility, here is now a tendency to introduce devices which limit everse action without impairing the normal steering n, although this reverse damping must generally be at xpense of the self-restoring tendency.

rtain general points are common to all steering systems. wheel-track is most important. Most people are aware the front wheels have a tendency, when the car is moving, oread away from each other ; so that if the wheels are lead parallel at rest, in motion they will be splayed out. splay, it is true, will be comparatively slight ; but even is no more than a quarter of an inch its effect will be tly seen in " scrubbed " tyre treads. Most front wheels therefore set with an initial toe-in of $\frac{1}{8}$ in.

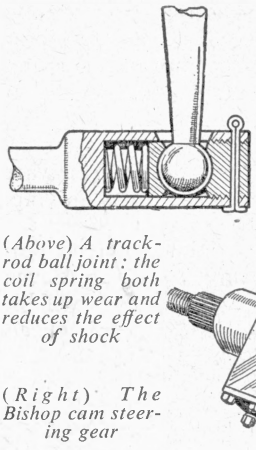
yre pres- s are one hose simple, ious points ch by their y simplicity overlooked. steering tem in this rld can give ts best unless front tyres e correctly d equally flated. ually: that is



A modern version of worm-and-nut steering gear : the Burman-Douglas



The front-drive Citroën car makes use of a special rack-and-pinion steering, with, of course, a track rod in two separate sections, one to each wheel



(Above) A track-rod ball joint: the coil spring both takes up wear and reduces the effect of shock

(Right) The Bishop cam steering gear

most importan
There is a drag o
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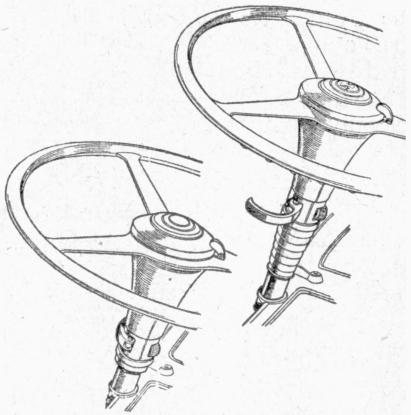
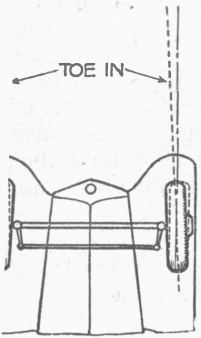
pressure. On th
extra - low - pressur
tyres popular to-day
a loss of two pound
pressure is enough t
disturb the accurac
and comfort of th
steering.

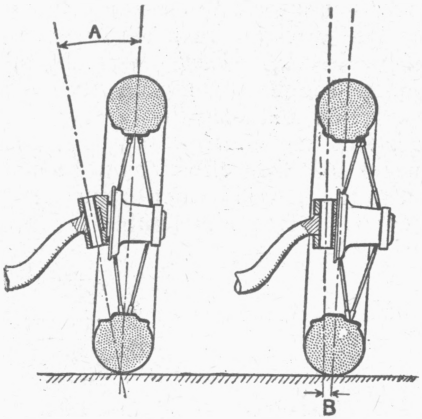
It is interesting t
note that the adven
of softer fron
suspensions and in
dependent fron
suspensions has had
considerable influence on modern steering designs. Th
vertical movement of front wheels having become greater, th
necessity for very accurate geometry in steering connectio
layout has increased. Moreover the current desire to secur
silence of running throughout the car entails that considerabl
damping of the transmission of road noise from wheels to coachwork has to be carried out, and rubber bushings are extensively used for this purpose. It is necessary, however, to arrange matters so that the rubber bushings do not introduce too much flexibility in the suspension and thus in the steering connections. Some of the post-war cars show that considerable attention has been paid to these matters,



Bluemel telescopic steering column adjustment above, unlocked and extended; below, locke and closed. Many makers now fit the devic



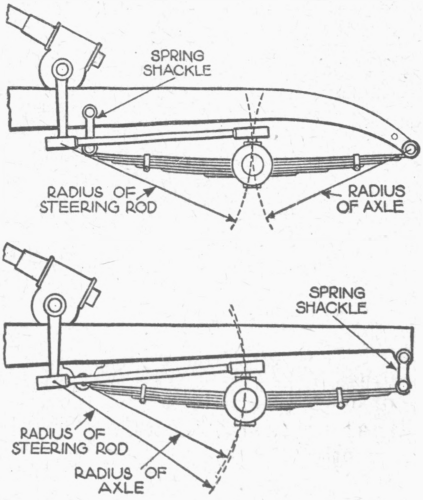
e revolving front eels tend to spread out ; y are therefore " toed " about $\frac{1}{8}$ in so that running they will pull themselves parallel



(Left) True centre-point steering, where the angle A has its apex at the point of contact of tyre and road, is rarely used although it is approached by inclining the front wheels outwards at the top, in conjunction with a more nearly vertical king pin. Centre point steering usually makes the car unstable. The usual difference is shown at B

ıd the ideal of a ght but very ccurate steering is eing sought with onsiderable uccess.

When steering is ınder discussion the erms "over-steering" and 'under-steering" ıre liable to arise.



Comparison of the movements of the steering rod and the axle : above for a rear-shackled spring and below for a front shackle. Rod and axle movements should be coincident ; if there is a big disparity wheel wobble may result. On most modern cars the steering box is mounted at the extreme front and a trailing drag link is used in conjunction with a rear-shackled spring

Over-steering means that the car tends to steer further in selected direction than the driver intended by his moven of the steering wheel. It results in the wheel having to pulled round slightly in the opposite direction to correction and keep the car on its exact course. This is cause of having to "saw" at the wheel. Under-stee means that light effort has to be maintained to hold the on to the desired corner or curve. A slight degree of un steer is therefore preferable.

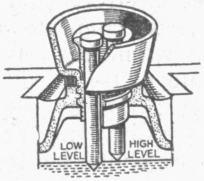
CHAPTER 10

Electrical System

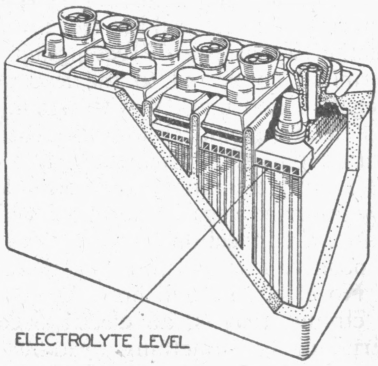
IT is an interesting fact that most people regard electricity as a mystery, a thing which is much harder to understand, more subject to peculiar troubles, than any other part of the car's engine or chassis. As a matter of fact, electricity in relation to the car and its engine is a matter of comparative simplicity, and it is not at all necessary to understand the full theory which underlies the production of electric current or its subsequent behaviour.

As far as the car is concerned, the heart of the electrical system is the accumulator, or, to give it its other name, the battery. This is simply a means of storing electricity, and consists of two sets of rectangular plates in a special box, one set holding a paste of lead sulphate, the other a paste of lead peroxide, and the plates alternate.

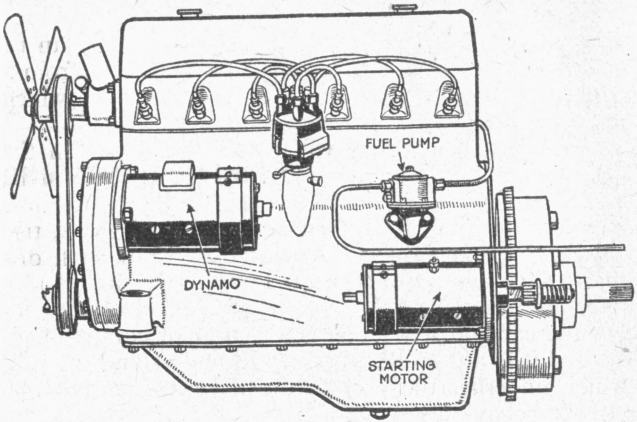
For purposes of convenience the plates are made up into sets in cells, and roughly speaking 2 volts pressure of electricity can be obtained from a cell. Each cell can be



Lucas prismatic level indicator and special easy-fill vent plug, which need not be removed when the battery is topped up. Distilled water is poured in till both glass rods appear dark on top



The interior structure of a lead-acid battery, showing how the positive and negative plates are interleaved with separators



Arrangement of the dynamo and starting motor on a typical engine ; the dynamo is here driven by the timing chain but more usually by a belt

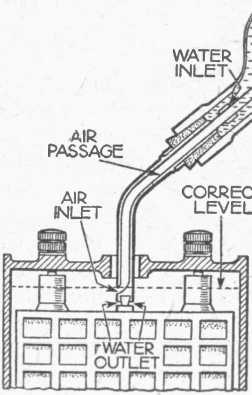
identified because it has a filler cap, and so if there are three filler caps the complete battery is a 6-volt, while if there are six it is a 12-volt or maybe there are two batteries, each of 6 V, coupled together to give the necessary 12, and in certain instances two 12 V batteries are coupled together to give 24 V.

In each cell there is a liquid which in theory consists of one part of sulphuric acid and five parts of distilled water, this liquid being sometimes termed the electrolyte. It is of interest that each cell has two terminals, each connected to one of the two groups of rectangular plates within the cell. The terminal connected to the lead sulphate plates is called the negative and marked with a minus sign ; that connected to the lead peroxide plates is called the positive and marked with a plus sign. When the two cells are connected together as a complete battery, one terminal of an end cell will be positive and the negative terminal will be at the other end of the battery, connection between the cells being made permanent, a positive terminal to a negative and so on.

No electricity will flow through the battery unless there is a circuit, that is, an electrical connection from one battery terminal to something needing electric current through a switch, and from that a connection to the other terminal of the battery. Current is conventionally said to flow from the positive to the negative.

The process is not continuous because the battery is gradually expended, but the advantage of the battery is that it can be re-charged, which is simply done by passing a current from a dynamo to the battery and so restoring the electricity which has been expended.

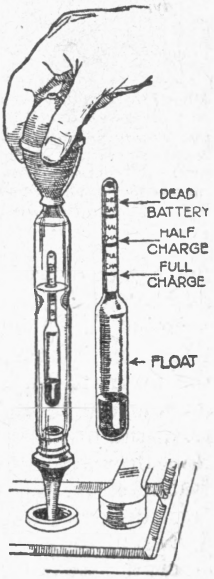
The efficiency of the battery will depend not only on the condition of the plates, about which nothing much can be done, but on the level of the liquid therein, which should just cover the plates, and as the water is liable to evaporate, this level should be maintained by refilling the battery with distilled water through the fillers provided, distilled water being necessary because ordinary tap water is harmful to the plates.



A battery-filling device which automatically prevents over-filling

Vaseline should be smeared over the terminals, because a certain amount of water and acid is liable to be spilt about the top of the battery, and will corrode the terminals and the wires leading to them.

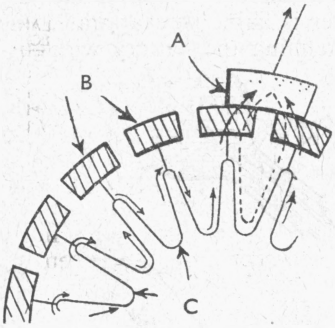
It will be seen that the battery cannot maintain the supply of electricity unaided; therefore a dynamo has to be provided, driven by the engine and connected to the battery through a series of controls and switches. Roughly, a dynamo consists of a machine which rotates an electrical wire in the space between two electro-magnets, or in other words a machine very similar to a magneto. But as the current required has to be continuous instead of spasmodic, as in the magneto, the wires coiled on the armature are led each



Hydrometers may be graduated "verbally", as here, or, more scientifically, may carry a numerical scale

to a strip of copper insulated from its fellow and arranged circle, the whole being called a commutator. Carbon electi blocks are pressed by springs against this commutator, so pick up the current, and some of the electricity tha created is used to control the strength of the dynan electromagnets.

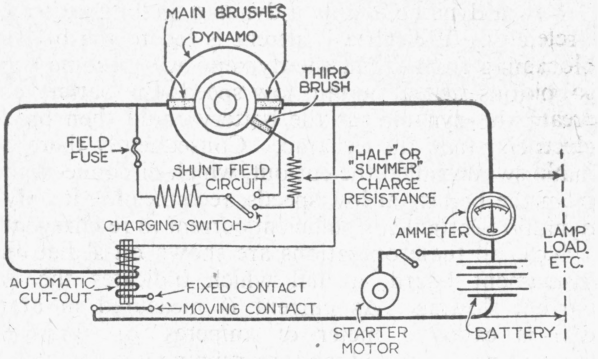
Normally there are two brushes, as these carbon blocks called, and sometimes th are three, the purpose of third being to control current passing to the electi magnets and so to control t output of the dynamo, whi depends on the strength the magnet. But as tl system is not altogeth satisfactory, it has given pla to a system called constan voltage control.



Theoretical plan of the commutator. A is the positive brush, B represents the commutator bars, and C the armature coils. The commutator, rubbing against A, delivers the current from each bar in turn, giving a continuous effect

What is called constan voltage control is really quite simple method c governing the output of th dynamo in accordance wit the work it has to do, an the whole of this control lie in a small mechanism termec the regulator and usually housed on the engine side of th dashboard and sealed in a metal case.

Briefly, what happens is this : The output of the dynamc will depend on the strength of the magnets round the armature ; the magnets being electromagnets, their strength depends on the current flowing round them. This current is by-passed from the main supply created by the armature. All that has to be done, therefore, is to vary the current to the field magnets. If, therefore, the armature current is carried round an extra electromagnet and that magnet is made to attract one half of a switch, the switch can be made to open when the magnet strength reaches a pre-determined point. When the switch opens, the current for the main field magnets has to pass through a resistance and is therefore weaker. That in turn reduces the output of the dynamo. It is not quite as easy as that, but that is the basic idea.



Circuit of the third-brush or constant-current dynamo

Further, if the state of charge of the battery is also made influence the electromagnet operating the switch, then the te of charge of the dynamo will be varied automatically ith the state of the battery and over-charging will be avoided. hat is why the voltmeter of a car swings over to a high reading s soon as the engine has been started in the morning; for a reat deal of current is being taken from the battery by the tarting motor and that current has to be replaced by the ynamo; but after a certain interval the voltmeter needle swings back to a low figure, which indicates the exact point at which the battery is restored to full charge.

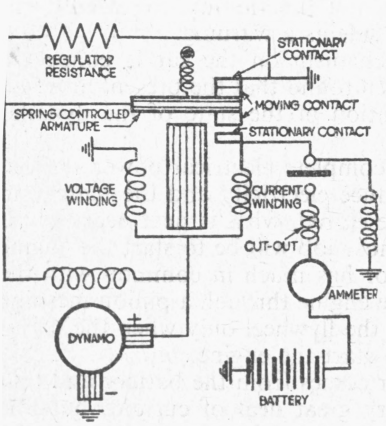


Diagram of the Lucas constant-voltage control system

Of course, it is necessary to arrange that if lamps or a windscreen wiper or any other electrical mechanism is switched on, the drain in battery current is immediately replaced by the dynamo, but the whole thing is automatic; and because the mechanism is sensitive, it is sealed in its metal case to avoid unskilled attention.

Now a dynamo is only a dynamo so long as it is producing electricity. If electrical current is fed to the brushes instead of coming from them, the dynamo will become a motor. It is obvious that at certain low speeds the battery could overpower the dynamo, as the battery could then produce more electricity than the dynamo. Consequently there is an automatic switch called the cut-out, which disconnects the dynamo from the battery at low speeds, reconnecting it only when the dynamo is producing sufficient current to re-charge the battery.

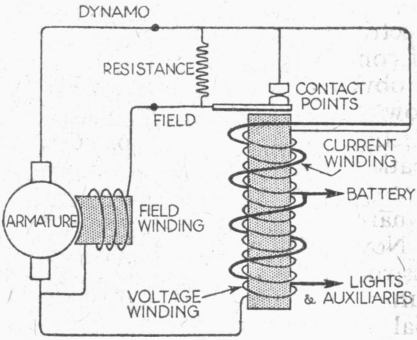
Now all these operations are shown on a dial on the car's instrument board, a dial which indicates the amount of current flowing. As current is measured in amperes, the dial is called a meter of amperes, or ammeter. When the engine is started and is running slowly, the needle on the ammeter shows zero. When the engine and therefore the dynamo speed rises, suddenly that needle will switch over to read a number of amperes charge. That is the moment when the cut-out has allowed the dynamo to feed the battery. The reading will persist until the battery is sufficiently charged ; then the regulator will come into action, the dynamo current is reduced, though not enough to allow it to be over-powered by the battery, and the ammeter needle comes back to a low reading. But both high and low readings are on the charge side of zero, as the reading on the dial indicates. If more current is being taken from the battery than the dynamo can replace, or if the dynamo is not functioning, the needle will swing over to the discharge side as a warning.

Not all the electrical mechanism on the car is connected to the ammeter, as it has been found that the present arrangement gives the truest indication of the state of the dynamo and battery.

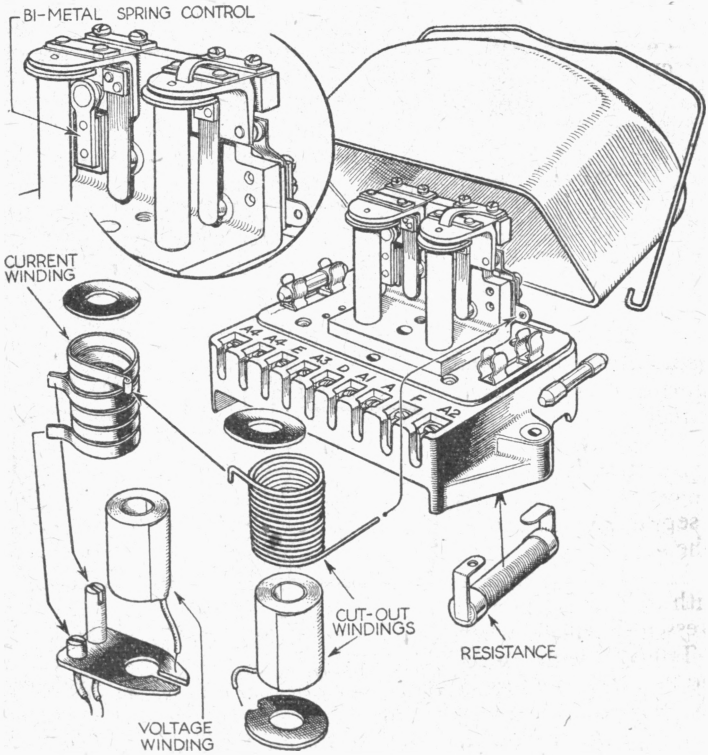
Now, having obtained a complete electrical power station, to wit, the dynamo, to produce electricity and the battery in which that electricity can be stored, what is next necessary is a separate electric motor whose job will be to start the engine when necessary. This motor has much in common with the dynamo, but is geared to the engine through a pinion meshing with teeth cut in the rim of the flywheel only when the driver presses a switch in order to start the engine.

The current for the motor comes from the battery and that motor naturally takes a very great deal of current, but fortunately only for a very short time, which is the reason why the wires to the starting motor are much larger than those to

(Right) Diagram of the compensating voltage-control circuit as used for most modern cars

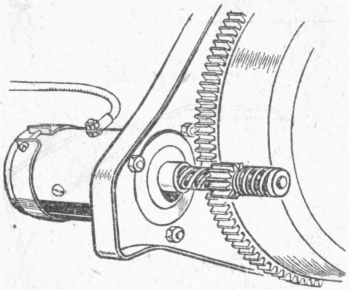


(Below) Details of the voltage control, cut-out and junction box of a modern car showing what the various parts look like in actual fact



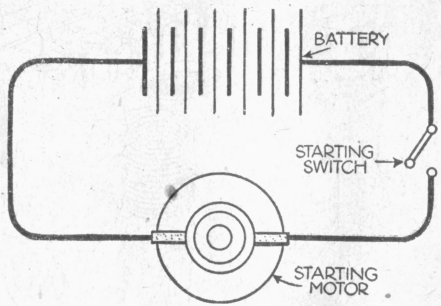
any other part of the car. The mechanism for gearing th motor to the engine is ingenious and interesting, and is know as the Bendix pinion.

The starter motor operates on a gear ring bolted to th flywheel. The Bendix pinion, by means of which the driv is transmitted, is a weighted pinion mounted on a coarse threaded sleeve extension of the armature shaft. When th starter circuit is completed the shaft revolves at considerabl speed, but the pinion, instead of turning with it, spins along the screwed sleeve through its own inertia. This brings it into gear with the toothed ring on the flywheel, which accounts for the slight clash heard. A heavy coil spring absorbs the shock of engagement to some extent. As soon as the circuit is broken and the starter ceases to apply power to the pinion, it spins out of engagement under the impetus of the coil spring. The teeth of both pinion and gear ring are eased off on their leading edges in order to assist clean meshing.

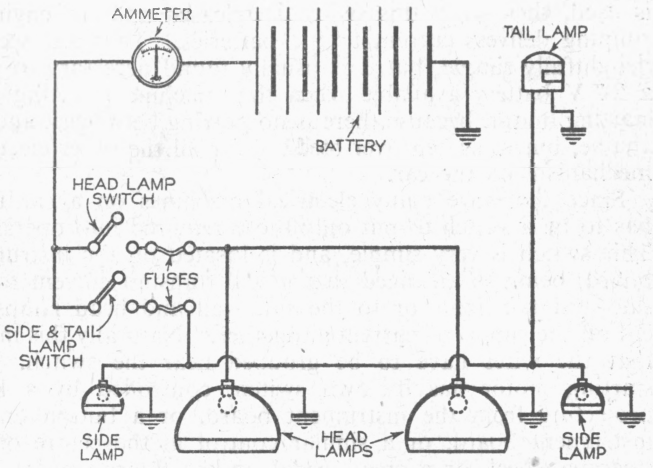


The Bendix pinion may be designed for "inboard" or "outboard" operation, so that it is pushed out to engage with the gear ring, or drawn back

But the latest form of this mechanism is slightly modified. Instead of the starting switch itself directing the current from the battery to the starting motor, that switch simply supplies electricity which causes what is known as a solenoid to operate, a solenoid being a coil of wire which when supplied with electricity will act as a magnet, and the magnetic power causes a



Circuit of the starting motor. The heavy currents involved make it a good plan to operate the switch by remote control, either through a solenoid or a mechanical link, so that the switch can be kept on the starting motor case



Elementary lighting circuit illustrating single-pole wiring with "earth return"

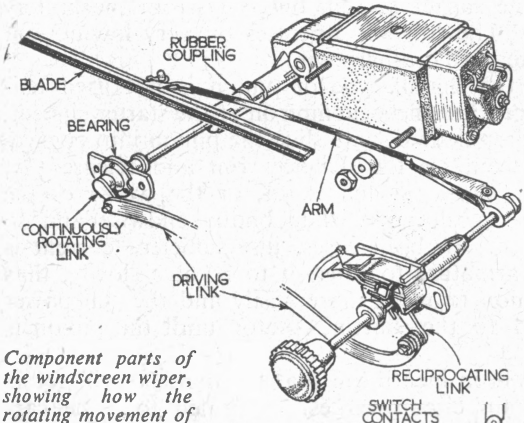
od in the solenoid to move. Movement of the rod switches he main battery current on to the starting motor, so it is iot necessary to have the heavy cables run all the way from he battery to the starter switch, but only from the battery .o the solenoid. The solenoid operates on very low current ind can therefore have ordinary wire.

Furthermore, the Bendix-type of pinion is not used universally any longer, but the switching on of the starter current, acting through the solenoid, may slide the pinion into engagement with the teeth on the flywheel rim and release that pinion when the starter switch is off, or the whole of the starting motor armature may slide bodily endwise and so engage the pinion. In both cases, just sufficient current is supplied to the armature to cause it to revolve slowly, thus allowing the pinion to mesh more easily and the full power is not delivered to the starting motor until the pinion is in gear.

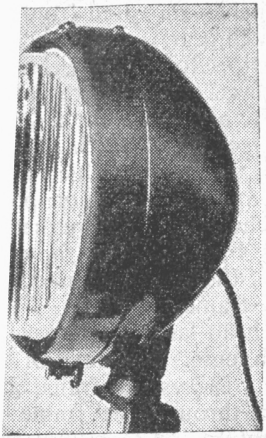
It has already been mentioned that the dynamo will act as a motor in certain circumstances. That led to some cars having dynamo and starter combined, and called a dynamotor. The dynamotor is usually mounted at the front end of the crankshaft and turns the crankshaft when the starter switch

is used, then when this switch is released and the engin running delivers current to the batteries. The idea seer delightfully simple, but it is usually found necessary to h a 24 V battery available when this machine is acting a starting motor, because there is no gearing between it and engine, but to switch over to 12 V for all the other electri mechanism on the car.

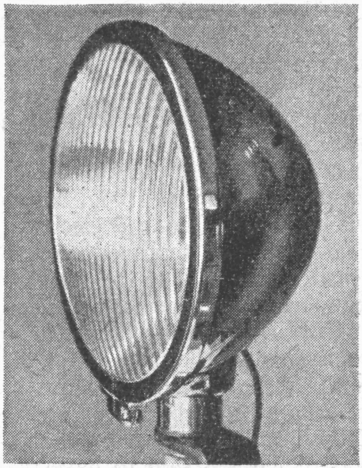
Since there are many electrical machines on a car th has to be a switch to put only those required into operatic This switch is very simple, and is located on the instrume board, being so arranged that it will transmit current to t side and tail lights or to the side, tail and head lamps, cut off the supply of current altogether. Naturally this mea that the wires have to be grouped near the switch. Tl starting motor has its own switch, controlled by a knc projecting from the instrument board, or a button on th instrument board, or a similar control in the centre of th steering wheel, or a small pedal on the floor boards. Th lights inside the car have their own switch, the horns ye another, and each windscreen wiper again may have a separat switch. Attached to the brake pedal is another switch whic operates a lamp at the rear to show that the car is stopping and on the steering wheel, as a rule, is a switch which wil operate the traffic signals. Yet one more switch is under the floor boards near the base of the gear lever, so that when the latter is moved to the reverse slot, this switch lights a reversing light behind the car. Fog lamps, if fitted, usually have extra



Component parts of the windscreen wiper, showing how the rotating movement of the motor is converted to a reciprocating action for the wiper blade



ıe of the special flat-top beam xiliary lamps fitted by many ivers as fog or pass-lights—the Notek



Another flat-top beam anti-dazzle and fog lamp — the Trippe. The flat-topped beam formation results from use of a divided reflector in conjunction with the spreading effect introduced by the special front glass. A special V-filament bulb is also used, the front of which has an integral mask to shroud direct forward rays

The modern tendency, which will become more evident in due course, is to build the head lamps into the front of the car, thus helping to reduce wind resistance. A still more practical advantage of this arrangement is that cleaning is simplified for the owner. Before the war this practice had been exemplified on a number of Continental and American cars, and, in this country, had been adopted on the latest Morris Eight (left), on which model combined head and side lamps are fitted. On a number of post-war British cars — for example, Riley, Bentley and Armstrong-Siddeley—the built-in head lamp policy has been newly adopted

switches as well ; but all these switches are wired from distribution point just behind the switch gear.

Originally cars had two sets of wires for every electr part, one along which the current flowed outwards, the ot along which it returned to the battery, but it speedily beca apparent that only one wire was necessary, and that is insulated wire, insulation merely being a wrapping which st electricity from escaping, carried from the distribution pc via the switch to the electrical mechanism. The return that current is arranged quite simply by connecting the el trical mechanism to the steel frame of the car and connecti one terminal of the battery also to the frame.

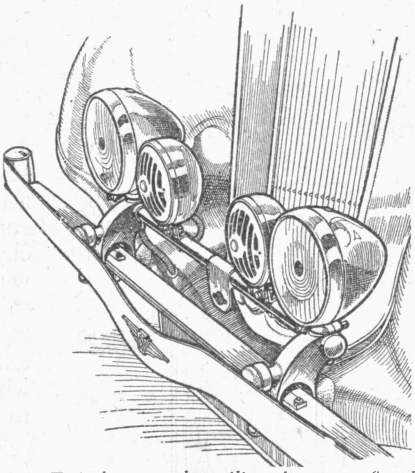
Current therefore flows to, say, a head lamp along a wi then through the filament of the bulb, enters the metal of t lamp and through the lamp bracket reaches the frame a returns to the battery. The return through the frame rather oddly, known as the earth return. A car with tv sets of wires is said to have two-pole wiring, while the sing wire system is called single-pole wiring.

Now it is quite obvious that if one wire became frayed s that the bare metal could touch the frame, electricity, whic has no particular desire to do any work, would prompt escape back to the battery, and as this path would be eas a rush of electricity would ensue, washing, or short circuiting the battery. Moreover, the lamp, or whatever it was tha wire served, would not operate. Accordingly, each wire i fed with electricity through a fuse, that is, a very thin wire o special metal generally mounted inside a small glass tube and the business of this fuse, as its name implies, is to mel if there is a sudden rush of current through it, so a short circuit causes the fuse to switch off the current. Fuses are nearly always grouped at the distribution point, where all the wires concentrate, and spare fuses are usually supplied nearby for immediate use.

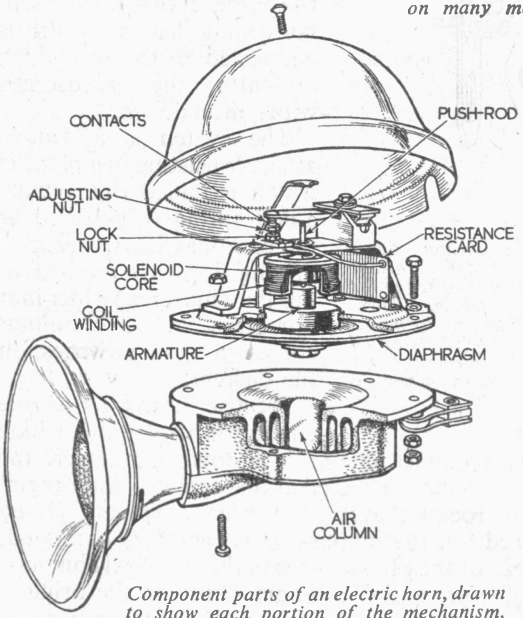
Another change has been made in modern cars, which is that the positive terminal is connected to the frame while the negative terminal has all the wiring, the current therefore apparently flowing in the reverse direction to that already described.

Modern wiring is very highly specialised. For each make of car nearly all the wires are formed into what amounts to a multi-strand cable, with leads off as and when required, and the whole designed so that it can be fitted to the chassis

n the minimum time vith the least possible kill. That, of course, nakes it less easy to race a fault in any ndividual wire, though admittedly it makes it ess probable that a fault will occur. And in consequence each wire is identified by a colour which continues from one end to the other and can be recognised accordingly. The whole assembly of wires is termed a harness.

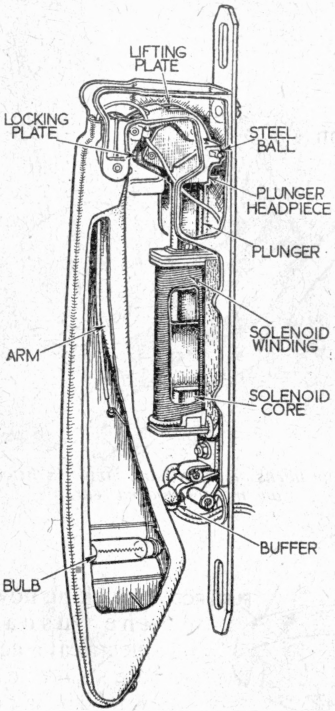


Twin horns and auxiliary lamps as fitted on many modern cars



Component parts of an electric horn, drawn to show each portion of the mechanism. The solenoid vibrates the diaphragm, thereby causing the horn to sound

Taking now the usual electrical accessories which are fitted to most cars, the windscreen wiper is operated by an electric motor through mechanism which is as a rule one of two different types. In the first, the armature shaft of the electric motor drives a worm, which



Mechanism of the trafficator signal arm, exposed to show the various working parts. Current switched to the solenoid attracts the plunger downwards, raising the signal arm by means of the lifting plate. When fully raised the arm is locked by the locking blade which is released when current is switched off

in turn drives pinions and a gear which rotate a crank and the equivalent of the small end of the connecting rod for that crank oscillates a rod to which the windscreen wiper blade arms are attached. The second is considerably simpler. The electric motor drives a shaft with a rubber coupling through gears. At the end of this shaft is a very short crank arm, the crank pin of which is attached by a rod to the crank pin of a much longer arm. As a result, the small crank rotates, but the large crank only oscillates, and that in its turn is connected to the rod which oscillates the windscreen wiper mechanism.

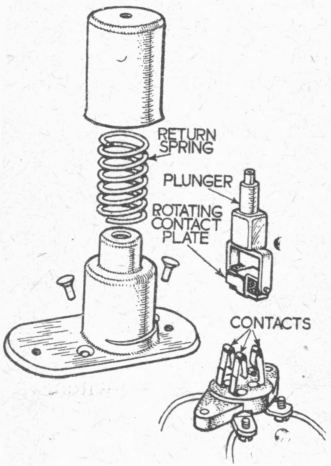
The switch is a simple affair, consisting of a plunger which is pulled out against a coil spring or released as the case may be, whereupon driving dogs are meshed to put the windscreen wiper into operation, while simultaneously a cam switches on the current.

Electric horns as a rule consist of a solenoid, which is a form of electromagnet able to suck down a plunger, the plunger in this case being connected at one end to a diaphragm, at the other to the rocking lever of electrical contacts. When current is switched on, the diaphragm is therefore oscillated, because movement of the plunger breaks the electrical contacts, whereupon the plunger and diaphragm return to the original position, current is switched on again and so the diaphragm is vibrated rapidly. The effect of this vibration is to cause

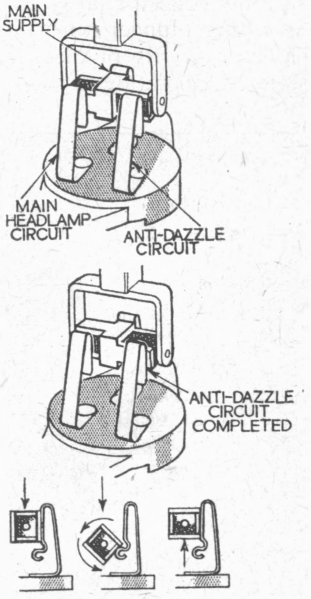
olumn of air consisting of sound waves which make the uired sound.

Traffic signals again have a solenoid. The plunger operated this solenoid has a claw-shaped head made up of a lifting te and a locking plate. The lifting plate descends, pulls wn the lifting pin, whereupon the signal arm lifts and the ing pin slides inwards until it is locked by the locking ıte. That holds the signal arm in position until the current switched off, allowing the arm to fall automatically. Control the signal arm is effected by a switch in the boss of the ering column, accessible when the steering wheel is moved wards free from the splines on the steering column.

The lever which operates the switch moves sideways, against coil spring, switching current to the solenoid. Simultaously the lever is locked in position by the downward ovement of a plunger operating on a steel ball. The outer ıd of this plunger is hinged. A cam moving with the steering



Mechanism of the pedal which actuates the switch between the fork of its plunger. The fork is below the pedal and connected to it



(*Right*) *At the forked end of the rod, controlled by a pedal, is a switch which rotates, first making contact with the main headlamp circuit, then with the anti-dazzle circuit, and so switching on both headlamps or one headlamp with its reflector dipping*

wheel can therefore move this end aside, so long as the steer wheel is turned in one direction, but forces the plunger up the steering wheel returns to the straight-ahead positi Upward movement of the plunger causes the switch lever return to its normal position, cuts off the current to t solenoid and releases the signal.

The control for the dipping headlight is, as the drawi shows, a very simple piece of mechanism, the pedal acting agai a coil spring and depressing a plunger which has at its low end a fork. Between the arms of the fork is a rotati contact plate. The first downward movement of the ped causes this contact plate to rotate, so that current is switche off the right-hand headlamp and on to the dipping mechanisn whereupon the left-hand headlamp beam is depressed an turned to the side. A second movement of the plunger agai rotates the contact plate, switches on the right-hand headlam and returns the dipping reflector to its normal position. Th dipping reflector also is controlled by a solenoid, whos operating plunger pushes on an operating bracket, tilting th reflector on its pivots against a return spring and simulta neously operating a switch which cuts off the right-han

Built-in enclosed number-plate, illuminated from behind. Note the stop and reverse lights

headlamp. Alongside the solenoid and switch is the fuse which guards this circuit.

Some cars now have a different system whereby the headlamp has not a dipping reflector, but the bulb has two filaments, of which one is used for normal lighting, the other to give a reduced and out of focus lighting, so that the headlight beam is thrown down on to the road.

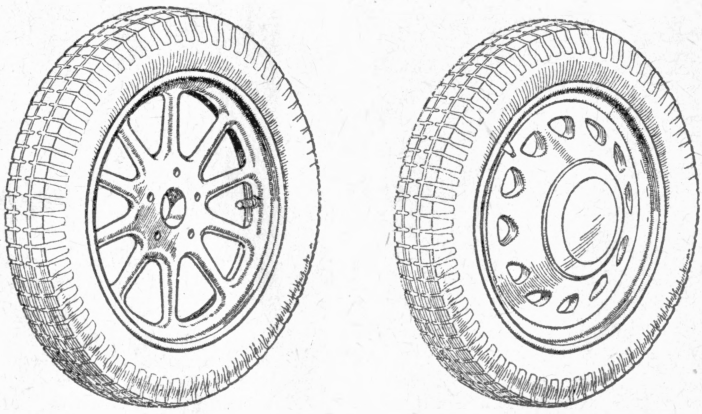
For the stop-light switch, the brake-pedal movement as the brake is applied pulls a rod which in turn causes two contacts to switch the current on to the stop light, a spring breaking the contact as soon as the pedal is released. Then the sideways movement of the gear lever into the reverse slot depresses a plunger which in turn brings a disc in touch with the contacts and switches on the current to the reversing light at the rear of the car. A coil spring breaks the contact as soon as the lever is moved back into neutral or into one of the forward gear slots.

CHAPTER 11

Road Wheels and Tyres

CONSIDERING the apparent limitations of design, it is remarkable how many different types of wheel have been evolved at one time or another. They may be classified under three main headings : first, that in which the wheel itself is a fixture, which includes both the earliest experiments and all later wheels with a separate detachable rim. Second, the bolted-on-at-the-hub variety, including the steel artillery, the plain disc, the wire wheel, and all types of the wheel known as the " Magna ", in which the fixing nuts are hidden behind a cover-plate. Third, there is a type of wheel used on expensive cars and sports and racing machines : the splined-on wheel.

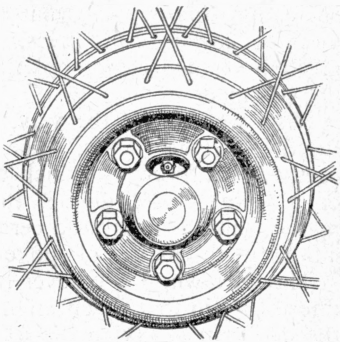
The earliest cars rode upon wheels of exactly the same type as used by the ordinary cart, complete with shrunk-on iron tyre. Subsequently there appeared the refinement that can still be seen on horse carriages, a solid rubber band tyre let into the iron rim; and about the same time as this innovation a primitive rubber-shod wire wheel was sometimes used.



The old hollow artillery type and the latest " Easy-clean " wheel which has its fixing nuts concealed behind an ornamental cover

When the first pneumatic tyre appeared—simply a reinforced air-tube—the sides of the iron rim were extended upwards to form a U in order to retain the tube in position. Of course there was then no idea whatever of making wheel or rim detachable.

At this time car wheels were still universally of large diameter, and the back wheels were frequently bigger than those on the front—another legacy from horse carriages.



A bolt-on wire wheel with the hub cover removed. The greaser, not by any means a universal fitting, can be reached in some cases without removing the wheel

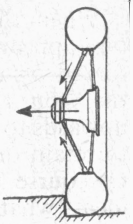
Of course, with the introduction of pneumatic tyres came the puncture, and the Stepney wheel appeared : a spare tyre on a rim fitted with clamps. To use it, the punctured wheel was jacked up and the " Stepney " was fixed on to the outer edge of the wheel rim. From the " Stepney " it was a logical move to make all the rims removable ; America chose and developed this solution of the problem, evolving the split rim to give the easiest method of dismounting tyres from wood-spoked wheels.

Other countries, notably Britain, preferred to develop the " artillery " type of wheel, made of steel and built from two pressings welded together. This wheel was demountable as a whole instead of the rim only.

Contemporary with the steel artillery wheel (frequently known as the Sankey from the name of the firm that popularised it) was the disc wheel. This was popular on the Continent, and in America, where a split rim was applied to it. It never became much favoured in this country, save for a short time ; one important exception was the Armstrong Siddeley that for years had an interesting wheel, representing a compromise between the demountable rim and the detachable disc, for it was a rim with part of a disc, the large central hole in fact registering with the brake drum.

From the disc wheel has evolved the modern short-spoked " Easy-clean " wheel, which is a dished disc pierced with apertures forming " spokes " ; it has a bolt-on hub with an

enclosing cap. Like so many of the parts of the modern car, it is a pressing, and strength is given by flanging the spoke apertures as they are stamped.



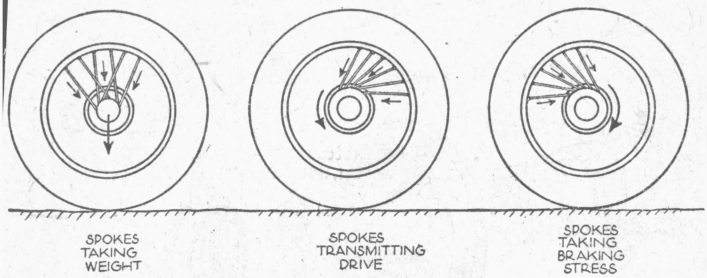
Disc wheels, by the way, must not be confused with wheel discs. The latter are spun or pressed metal covers, which enclose the spokes of a wire wheel, giving, in the opinion of many, a neater look, and certainly saving much labour in the matter of spoke cleaning.

The wire wheel, whatever its type of fixing, is interesting in that it represents a totally different approach to the problem of taking the weight of the vehicle. In all other types of wheel the principle involved is that of the car resting upon the lower half of the wheel structure, which is therefore in compression. The mechanical strength of the spokes of a wire wheel is obviously insufficient to take any compression such as the weight of the car ; a steel spoke is, however, capable of enormous strength under tension. In the wire wheel, therefore, the car is hung from the upper half of the rim by the spokes connected to the hub.

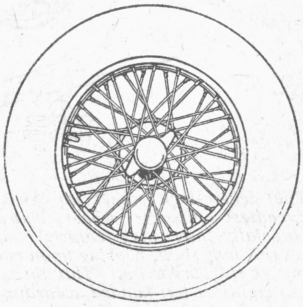
Building a wire wheel is one of the most difficult tasks imaginable ; the layman's eye sees a meaningless tangle of spokes but the wheel builder follows a strict pattern. There are many such patterns, but in all cases the extreme cleverness of the scheme is the same ; a structure strong enough to cope with all the strains and stresses of a heavy car is evolved from a light rim, that one can almost buckle with one's hands, a bunch of thin wire spokes certainly light enough to bend in the fingers, and a hub shell. When one considers just what the resultant structure has to do, and can do, one feels a distinct respect for the inventor !

The wire wheel is lighter than its counterparts. It also possesses a springy resilience which gives it a big margin of resistance to deformation. In the bolt-on variety it is tending to disappear, for the modern pressed steel spoked type is so much easier to clean.

A special form of wire wheel was used extensively by the Ford concern ; the spokes, of much heavier gauge than usual, were welded to hub and rim. This wheel was cheaper to make than the tensioned variety, from which it departed completely in principle ; nevertheless it was an excellent wheel, light and immensely strong.



The spokes of a wire wheel resolve themselves, on study, into these specific groups, each with a different purpose. Finally the complete wheel may appear as on the right, though there are innumerable variations

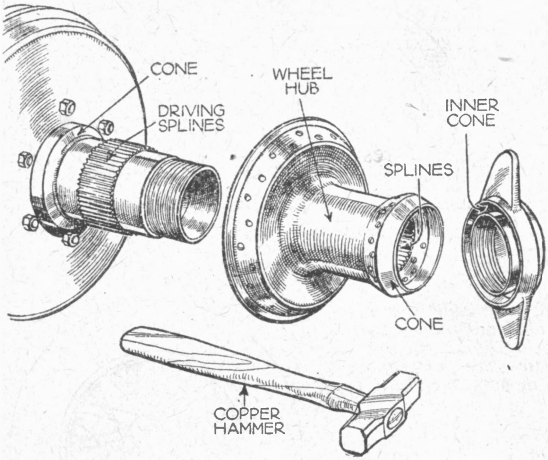


The centre-lock wire wheel is employed on sports and racing cars (for which it was originally evolved) and on certain expensive makes. It represents the simplest and quickest of all wheel fixings ; the car hub is splined, in other words it has grooves cut in its surface, and exactly corresponding grooves are cut on the inner surface of the wheel hub. Thus when the axle has been jacked up, the wheel is merely slid into position.

Then on the end of the car hub, which now projects slightly, there is a thread, and with this is engaged a large-eared nut, coned internally, to engage with the coned edge of the wheel hub. Sometimes the nut is not eared but has hexagonal faces for a spanner; sometimes it has holes drilled at intervals in its circumference, by which a special shifting tool can grip it.

The point contact (resulting from the downward pressure of the car's weight) between the cone on the hub and that on the fixing nut produces an eccentric winding effect tending always to tighten the nut. The threads are appropriately right- and left-handed.

With the eared nut of the original Rudge-Whitworth pattern it is necessary to have a copper or lead hammer with which to clout the ears and so undo the nut. To the hexagon-type nut, such as is fitted to pre-war Bentley and Rolls-Royce



The centre-lock wheel was originally planned to give the speediest possible wheel changing, for racing purposes. Specially interesting features include the internally coned ends of the hub shell, bearing upon corresponding cones on the hub and in the eared cap. This thread on which the cap screws is cut right- or left-handed according to the hub being at the near or off side, so that the cap has no tendency to unscrew itself

cars, a long-handled spanner is first fitted and the " persuasion " helped by judicious blows from a soft-headed hammer Rolls-Royce have their own kind of centre-lock fixture, in which a central screw is first released before the hub nut is unscrewed.

Strictly speaking, as an integral part of the wheel, the rim ought to be discussed before the tyre ; but as it is the tyre that determines the rim structure it will be better if the logical order is reversed.

The first tyre, as we saw, was merely a development of the iron band shrunk red-hot on to a cartwheel. Then came the solid rubber band, then the single air tube ; so that it will be seen that the idea of a tough cover and an inner air tube came quite late in the history of the car.

The story of the pneumatic tyre is a fascinating subject ; but it is too large to cover other than very briefly in this handbook. To J. B. Dunlop is owed the fact that to-day cars are able to ride on air, and the Dunlop Company made the first

practical pneumatic tyre. Other famous names in the rubber world must not be overlooked : Palmer, associated with the first application of " cord construction ", for instance.

The Michelin firm were early in the field with low-pressure tyres, and the Goodyear concern developed the famous " All-weather Tread ". It is interesting to compare a modern tyre and its rim with the product of, say, twenty years ago. The first and most striking difference is in the section ; the old tyre is of little over half the " fatness " of its modern equivalent.

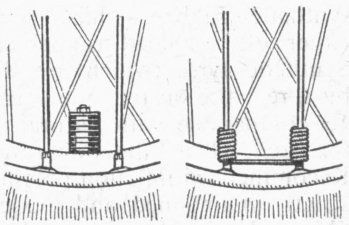
There is a striking difference in the method of mounting the tyre. Originally, when tyres were extremely unreliable, it was customary to fit security bolts, which positively located the cover and tube and prevented them " creeping " round the rim.

Tyres of those days were of the beaded edge type ; such a cover was put on by sheer strength with the aid of massive tyre levers, since the edge of the cover had enough elasticity to spring over the rim. It is not difficult to understand why someone introduced a split rim !

To-day's type of tyre is wired on, fitting being easy and merely a matter of knack based on a proper appreciation of the principles of construction. The tyre bead is inextensible, so that the 16-in " persuaders " of other days would only ruin the tyre by bursting the edge. Instead the rim has a well-base, there being a deep hollow in the centre of the rim section. If one edge of the cover is pushed down in this groove it will slip quite easily over the outer edge of the rim at the point diametrically opposite.

There is a vast difference between the old tyre pressures and the new. High-pressure covers of the past were pumped to 45 lb per square inch and more. The larger section tyres to-day work at from 23-35 lb, according to the size of the car. The extra-low-pressure tyre is intended for inflation to as little as 15 or 20 lb.

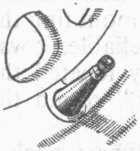
Long tyre life is, of course, the biggest forward step of modern times. People expect and get mileages of 20,000



If a car is to be driven fast it is desirable to balance the wheels rotationally. The tyre valve must be counterbalanced, either by bolting washers to the rim, or wrapping two or more spokes with lead wire

and more, whereas not so long ago if a tyre was good for 5,000 miles this was an achievement.

Tyre wear can almost be controlled. The man who is careless of his front wheel track, who habitually rides with under-inflated tyres or with the inflation pressures unequal, who never examines the treads and picks out small flints and sharp stones embedded therein, who allows oil to remain on his covers, who accelerates violently and drives on his brakes —such an owner will be lucky if he gets 12,000 miles out of a set of covers. Another man on exactly the same car may run a set of tyres 20,000 miles or more by giving them reasonable treatment.

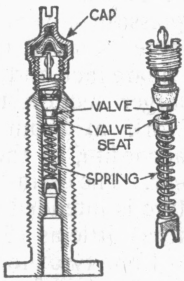


Dunlop rubber body low-pressure type of valve

It never pays to wear tyres right out. When the tread is worn completely smooth the liability to skid on wet roads is greatly increased, and if an accident occurs there is a possibility of a prosecution on the ground of driving the car "in a dangerous condition". While wartime conditions have created certain difficulties, the position as regards having tyres retreaded has eased somewhat, but this work cannot be carried out if the fabric casing is damaged.

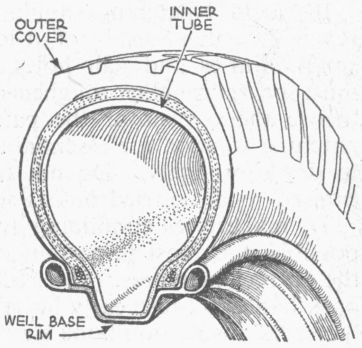
In post-war tyre equipment there is a marked tendency towards the use of rims with a wider base than formerly. Tyres mounted on a wider base have the side walls more nearly flat, and an increased resistance to side roll is gained. The stability of the car when cornering is improved, but the resiliency and therefore riding comfort are slightly diminished.

From 1943 to 1947 tyres were made of synthetic rubber, whilst retreads were either of reclaimed rubber or synthetic. Synthetic tyres (which are distinguished by a red disc on the side wall) are not as yet comparable with natural rubber tyres for reliability and wearing qualities. Recommended inflation pressures must be strictly maintained and moderate speeds observed. In short, everything must be done to avoid excessive flexing of the tyre and consequent overheating. Synthetic inner tubes cannot be properly repaired by ordinary cold patching and they must



Schrader tyre valve sectioned to show spring loaded valve

never be inflated to any great extent when out of the cover, otherwise they will become permanently stretched.



Section of a well-base tyre and rim

For tyres, and especially the larger sizes of tyres, synthetic rubber is not yet a perfect substitute for natural rubber. For one thing it is less resistant to the heat generated, and, as regards its use for inner tubes, is more liable to tear than the natural product. If a satisfactory mileage is to be obtained it is, therefore, necessary for a motorist using tyres and tubes made from synthetic rubber to observe greater precautions than he may have been accustomed to exercising in the past with ordinary tyres. The following advice on the subject should be carefully noted.

Synthetic rubber has some, but not all, of the physical characteristics of natural rubber. Tyres made from GR-S—a term employed for what was originally called Government Rubber-Styrene, although usage has altered it to Government Rubber Type " S "—contain a proportion of natural rubber ; generally speaking, the larger the tyre the higher the proportion of natural rubber incorporated to help the synthetic to withstand the stresses.

Whilst, within limits, liberties could be taken with normal tyres, this certainly does not apply to " synthetic " tyres. The ordinary precautions, such as maintenance of the correct pressures, avoiding of overloading and fierce braking and acceleration, and the regular removal of flints and stones, apply to a greater extent. Even the smallest cut in a tread or side wall should be repaired without delay, otherwise it is likely very soon to become a major repair job. Normal repair methods can be adopted, it being necessary at present to use natural rubber materials, and repairs should be carried out by qualified repairers. It is most important that tube repairs be vulcanised. Ordinary " cold " patching can be used to meet a roadside emergency, but the patch must be vulcanised subsequently without delay.

If " cold " patching should be necessary as a temporary repair the patch must be of at least 1½-in diameter for covering small injuries and nail holes, and the surface of the tube must be thoroughly roughened to destroy its surface glaze before the cement or the patch is applied. Two coats of patching solution are essential and each coat must be allowed to dry thoroughly. Do not forget to have a properly vulcanised repair carried out as soon as possible.

To make tyres containing synthetic rubber last as long as possible it is most important that they should be inflated to the correct pressures. Over-inflation and under-inflation are both liable to cause early failure. With a new car the manufacturers' instruction book should be consulted on the subject, and its recommendations adhered to most carefully. In other cases where doubt exists references should be made to an Authorised Tyre Depot.

Tyres containing GR-S are identified by a red medallion on the side wall with figures such as 10/10 superimposed. The figures, which vary, convey technical information to manufacturers and are of no significance to the user, beyond warning him that he has a " synthetic " tyre which must be treated accordingly. Markings have latterly been changed to the form " S5 ", the figures ranging between 3 and 7, and again conveying information to the manufacturer. Synthetic tubes are identified by a red stripe or a 1¼-in medallion near the valve.

The following procedure must be adhered to when fitting tubes made of synthetic rubber : Insert the tube in the cover and inflate it until it is nearly rounded out. A frothy solution of soap and water, made by adding sufficient hot water to soap to make a slippery solution and allowing it to cool, should be applied by means of a brush or a cloth swab to the base section of the tube, great care being taken to prevent the solution running down into the crown of the tyre. The tyre is then fitted on to the rim, making sure that the entire beads are clear of the well of the rim all the way round. Next, to ensure that all surfaces are properly seated, inflate to a pressure of 30 lb per sq. in., not allowing the tyre to hang loosely on the wheel while doing so and having first centralised the valve and pulled it firmly into place.

The tyre is then completely deflated by removing the valve core, and when it is quite flat it may be pumped up to the pressure recommended for its size and loading, and is ready

for use. It is most important that the tube should be properly lubricated and fitted, for otherwise it will be stretched thin in the region of the tyre bead and rim, which will cause premature failure. The rims should be thoroughly cleaned to remove rust and any bent rim flanges straightened before the tyre is fitted.

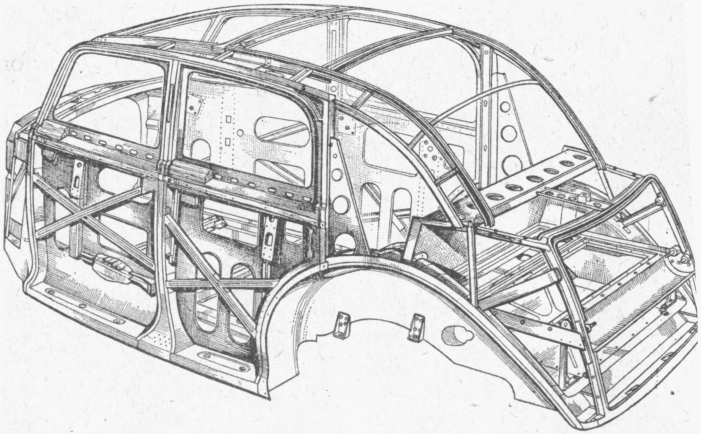
Nowadays the normal rubber outer cover and tube are available once more. By comparison this tyre is much easier to deal with, provided that care is taken to push the beads of the cover down into the well of the rim before levering the opposite side of the cover off the wheel. Very long tyre levers are unnecessary, but the very short lever often supplied is only suitable for use when the tyre has had a considerable run in mileage. With the modern inner tube of large section a certain amount of care is necessary when the tube is being replaced in its cover. Otherwise, the secret of a tyre's long life is maintenance, particularly maintaining the tube pressure at the correct limit, avoiding scraping the kerb and making sure that nails or flints are not allowed to remain embedded in the tread.

CHAPTER 12

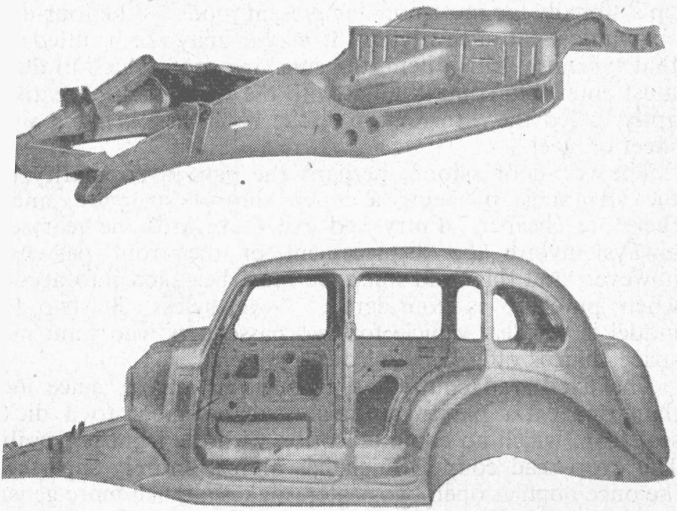
Coachwo

UNTIL quite recently it was customary to look upo car chassis as a complete unit, which was then tur over to the coachbuilding department of the manufactur or perhaps to some " outside " firm of specialist body c structors, for another unit to be added to it in the form o body. In other words, from an engineering standpoint t two were in little sense related to each other.

To-day an entirely different trend has been followed, that it is impossible to consider the car as a whole withc recognising that the body has become an essential part of t structure. With an ever-increasing number of popular ca the body forms extra stiffening to a chassis which is oft built lighter than would otherwise be the case. The body a steel structure of great strength, composed of a series



Modern bodies are considered as engineering structures, and used to increas the strength of the chassis. This drawing shows a body before it become part of the frame, and illustrates the obvious fact that the structure is reall a complete box section girder



o-day there is a general tendency to make the saloon type body part of the ıassis, instead of having a separate frame and body. These photographs ıow first the frame as a separate component, and then the frame and body welded together to make one member

elded pressings. Woodwork is eliminated save perhaps for ıe front floorboards, and ingenious systems of sound-eadening and cross-bracing prevent the development of ɛsonance noises.

The last stronghold of the hand-made, composite body—he specialist, individual productions of those great coach-uilding firms who have been making wheeled carriages for undreds of years—will last as long as there is demand for he car of distinction.

Nevertheless, even the hand-finished body is tending to-ards an all-metal construction, for the frame of the body is owadays often made of light steel girders instead of yester-ay's ash. Post-war development envisages the use of luminium alloy instead of sheet steel for parts that are not ighly stressed, such as bonnet tops, door panels, boot lids, nd perhaps wings.

Twenty years or so ago a " car " meant an open tourer. `o-day most people think instinctively of a saloon, and

undoubtedly the most popular present model is the four-door six-window car of this type. It may or may not be fitted with that typically British item, the sunshine roof, which in design must enter into some conflict with the transatlantic treatment aptly called the "turret top", the roof then being a single sheet of steel.

The two-door saloon, perhaps the next in popularity, has the advantage of being a much simpler structure, and is therefore cheaper. Entry and exit as regards the rear seats always involve the displacement of the front passenger, however, and this mild nuisance must be taken into account when purchase is considered. Nevertheless the two-door model is an ideal vehicle for two passengers who want more space than is offered by a coupé.

The fixed-head coupé has a restricted appeal, since more than one extra passenger involves banishment to a dickey seat from which no communication with the front is possible. The drop-head coupé, which has almost entirely superseded the once popular open two-seater, makes a much more general appeal, chiefly because an artistry of line can be contrived that, when the hood is folded, cannot be approached by any other body style.

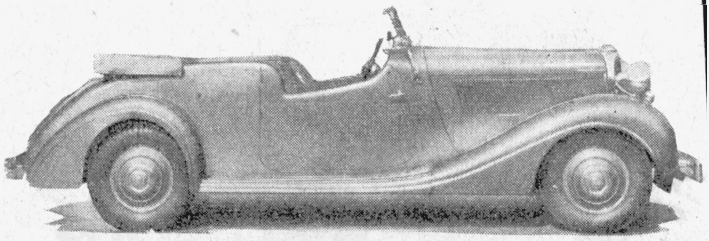
Often this type of car retains the looks of the two-seater but is in reality a cabriolet, or close-coupled style, with occasional seats between the front passengers and the boot, or luggage compartment.

A most useful scheme that had a much greater popularity on the Continent, and particularly in Germany, than here is the cabriolet four-seater, to give it one of the several names it possesses. There are four doors and of course one finds the accommodation of the saloon; the windows are glass and wind down, one in each door. Narrow plated frames hold the erected window, and the body is finished off with a canvas folding top that is yet a lineal descendant of the original "Cape Cart" hood.

The chief drawback to this body is æsthetic. Only a very few coachbuilders have successfully attained handsome body lines and avoided a clumsy appearance either in the open or closed position.

There are many variations on the drop-head idea. The Tickford, for instance, is well-known; and a Lancia was listed on which the massive, beautifully made top was folded down by an electric motor.

Three modern bodies which are not as far advanced towards streamline as some of the continental examples but are essentially practical. The top car is a Lagonda, the other two Rolls-Bentleys.



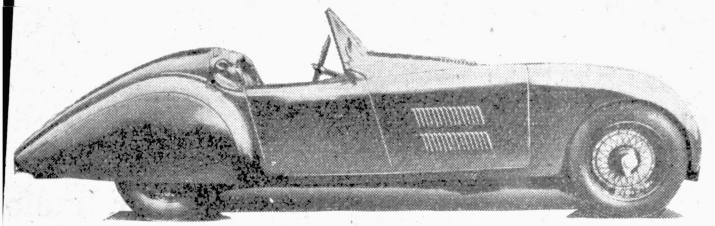
Sunbeam Talbot open car; a type that is becoming more and more rare

Safety glass is now compulsory in the windscreens of all cars; there are two kinds of this glass: laminated and toughened. Laminated is subdivided into plate and sheet, the difference lying in the grade of glass used. Laminated plate consists of two pieces of plate glass with a sheet of special celluloid material between them, the sandwich thus formed adhering together by the use of a special adhesive and the application of heat and pressure in manufacture. Laminated sheet is produced in the same way, but sheet glass is used instead of plate glass.

Toughened glass is a special grade of plate glass subjected to an annealing process. There is no sandwich, but the annealing so modifies the structure of the glass that it develops an almost armour-plate strength and an extraordinary capacity for resisting breakage through twisting and bending stress. When it is forced beyond the limit, it breaks up completely into a mass of small blunt crystals, which have been compared in appearance to bath salts.

Car finishes make an interesting study. Cellulose, which has now replaced the time-honoured paint and varnish, owes its resistance to wear to the absence of any outer skin. It retains its lustre because it is "the same all through". Petrol and oil destroy a varnished surface, but have comparatively little effect on cellulose. What does instantly attack it, however, is alcohol in any form, whether as "methylated spirits" or when mixed with the fuel in the form of alcoholised petrol. Great care should always be taken to avoid drips from the fuel hose on the coachwork. White blotches form which cannot be polished out.

Apart from that, however, cellulose is a really "tough



Sports type two-seater H.R.G. of advanced streamline design

proposition ". Surface scratches, for instance, can be cleaned away by the restrained use of cellulose polish. All cellulose cleaners do their work by removing a microscopic film from the surface, which at first may seem destructive, but which actually does not matter since there is no " surface " of separate character.

Then there is the still more recent type of finish, which seems to possess all the virtues and none of the vices. This is synthetic enamel, so called because its basis is synthetic resin, and its outstanding features are that it produces a porcelain-like surface of brilliant lustre. Further, it would appear that once the finish is thoroughly hard it is as near indestructible as no matter. Heat—within reason !—petrol, oil, alcohol, none of them seems to have any effect.

Unlike cellulose, it does not quarrel with other finishes. Cellulose, that is to say, will nearly always " lift " and blister stove enamel if it is applied over an old surface of this kind, which means that a special priming coat must be used. Synthetic, however, will go over any kind of undercoat, provided the usual rules of painting are followed : clean and grease-free surface, and dead-smooth, dust-free working.

CHAPTER 13

Car Radio

FITTING a car radio ten or more years ago was a major undertaking. In the first place the set itself was somewhat bulky, and finding room for it in the confined interior of the average British car was a pretty problem. The installation of the set was only half the battle, however, for even when this had been successfully accomplished there yet remained the long struggle against static interference created by the car's electrical system. Suppressors were fitted with a lavish hand—sometimes to the detriment of the car's performance—and to complete the task attempts had to be made to bond together the various large metal areas of the mixed construction body.

All this is now a thing of the past and to-day the equipping of a car with radio presents no special difficulty. The development of small radio components has led to a considerable reduction in the size of the set, with a consequent easing of the problem of where it can be put, in fact several sets have been specially designed to fit into the facia cubby hole.

By fitting the set with a metal screening case and by equipping it with numerous filters, the interference bogy has been largely overcome and as a general rule only a single suppressor in the main distributor lead is now necessary. The introduction of new and more efficient valves has reduced the demands made by the set on the battery of the car, the average set now taking only 4·4 amperes when operating on a 6-volt system or 2·3 amperes on a 12-volt system.

Car radio sets may be roughly divided into two classes, those built as one unit and those in which the loud-speaker, the power pack and the control head form separate units. The latter type are often more expensive but they have several advantages. Installation is considerably easier and, moreover, the various units can be located in the most convenient positions in the car. The control head can be mounted where it can be operated by either the driver or the front passenger,

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the loud-speaker can be positioned where it will give the best reproduction—and moreover can be of a larger diameter, which in itself will improve the quality obtainable—and the power pack can be situated adjacent to the battery.

Many post-war car radios incorporate push-button tuning of the type that has become increasingly popular for the domestic receiver and in fact one well-known model has no provision for manual tuning at all for its makers feel that this method is too distracting to the driver.

There are five different types of aerial from which to choose. Starting from the bottom and working upwards, there is firstly the under-chassis aerial consisting of wire or other conductors supported underneath the chassis. This type is completely hidden from view and is therefore popular with those who regard any external aerial as disfiguring to the coachwork. It is, however, liable to pick up interference re-radiated from various sources such as the brake rods and the exhaust pipe, and is also somewhat vulnerable should the car be driven over rough ground.

Cars fitted with a fabric roof can be equipped with a built-in aerial consisting of metal gauze, but this type has of necessity to be fitted by the manufacturer when the car is being built.

Possibly the most popular type is the telescopic whip aerial of the " fishing rod " type mounted alongside the scuttle or on the rear bumper. The latter position is to be preferred but can only be used with a set of the multi-unit type.

The roof-type aerial, consisting of metal rods supported on insulators on top of the car, is not very efficient and may pick up interference from the wiring leading to the roof light and the traffic indicators. In its latest form, however, it is mounted centrally on the car roof just above the windscreen and projects vertically upwards above the roof. This type has none of the disadvantages of the previous roof pattern and is rapidly gaining in popularity. It is efficient, it is situated at a point relatively free from interference and in many instances it can be lowered when not in use so that it lies horizontally along the top of the windscreen.

Finally, there is the old question of whether car radio distracts the attention of the driver and is thus a danger. Although it is impossible to make any definite statement, for so much depends on the driver concerned, it can at least be said that car radio is certainly no more distracting than a talkative passenger.

CHAPTER 14

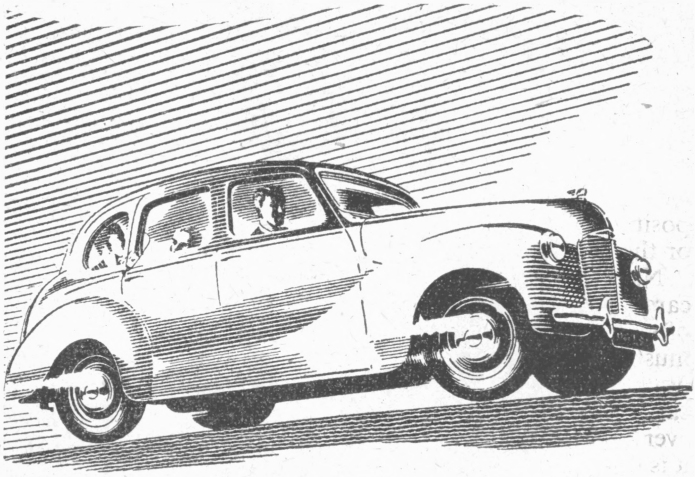
Caravan Towing

ARRANGEMENTS to tow a caravan are not quite as simple as they may appear at first sight. Firstly, there is seldom any provision for towing when the chassis is designed, nor does the designing staff make it easy afterwards to fit a suitable towing attachment. Consequently you see far too often a curious structure of rusty steel, roughly bolted in position without any regard whatsoever to the stresses entailed or the strength required.

Now the first thing to arrange is that the " pull " of the caravan is taken properly by some part of the frame capable of standing the load. This means that the towing attachment must be bolted to the frame side-members themselves, and not merely attached to a convenient portion of the luggage carrier or buffer, for neither luggage carrier nor buffer were ever intended to take the stresses set up. It is admitted that it is occasionally possible to use the buffer supports when these are substantial steel members coming straight from the main frame and forming an extension thereof. But in no circumstances whatsoever should the buffer be used as a direct foundation for the towing attachment.

As a general rule, the attachment will take the form of a steel member of roughly V-shape in plan, the two arms of the V being bolted to the frame by high-tensile steel bolts, the apex receiving whatever form of shackle is desired for the immediate connection to the caravan towing bar, the whole shaped to allow the car's spare wheel to be withdrawn from its compartment. But firstly the attachment must be designed with due regard to the fact that the frame of the caravan should be horizontal. It is most undesirable that the whole caravan, when attached to the car, should incline forwards or backwards when the car itself is level. The next thing to remember is that the principal stresses set up are due to starting from rest, stopping and what may be called plunging, that is, the tendency which always exists for the caravan to " buck ".

Wherever wheels can go . . .



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The actual force necessary to tow the caravan on its wheels creates the least of the stresses involved.

Now the effect of placing a towing load on the V-shaped structure already mentioned is to give the V and the ends of the frame of the car a tendency to close in, which ought if possible to be prevented by means of a strut, either across the frame or across the V. It would, as a matter of fact, be much simpler if the towing attachment could be of broad arrow shape, the shaft of the arrow-head taking the tow while the two side pieces form steadies, but that, unfortunately, is rarely possible.

If, as usually happens, the height of the towing eye of the caravan from ground level is greater than that of the frame, the towing attachment has to be arranged to fit, which introduces what is known as a couple. But the less the difference in level between the towing eye and the frame, the better the subsequent results. It is possible sometimes to overcome the difference in level by making a swan-neck in the shaft which carries the towing eye, but in that case, the towing eye shaft must not be allowed to revolve in its bearings.

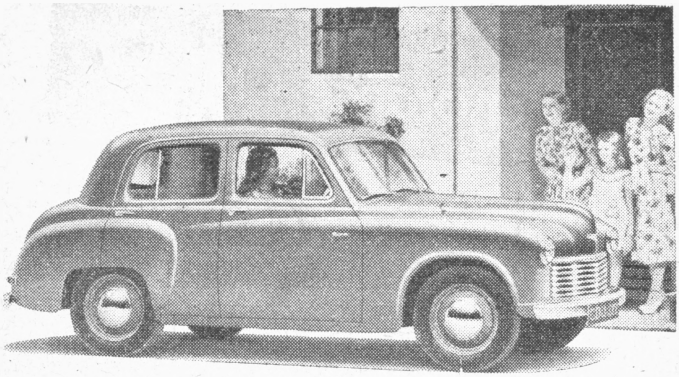
Next comes the question of the shackle. The ideal shackle consists of a ball on the end of the caravan towing bar and a socket on the car towing attachment, and the best advice to give anybody in this matter is to arrange for this form of shackle, unless it is absolutely impossible. The ordinary jaw and pin so often used necessitates making the pin smaller than the hole in the towing eye, in order to allow for the movement when the car has just passed the summit of a sharp little donkey-back hill, while the caravan is still on that hill, an action which also occurs on a bad road and in many other situations. If there is no clearance between the pin and the towing eye, the whole towing attachment has to bend in these conditions.

The alternative is a hook, but a hook has to be very carefully shaped to allow the caravan to follow accurately, is complicated and usually heavy. Both the pin and jaw and the hook make it much easier to unlimber or limber up the caravan, and of the three forms of attachment the hook has the advantage in this respect. Both hook and jaw and pin device must be secure, that is, once the caravan is attached it must not be able to free itself, however bumpy the road, whatever the speed of the car. That is comparatively simple to arrange if the jaw and pin is used, but not so easy with the hook.

If the caravan has to be towed often, the shackle must be durable, that is, the ball should be hardened and its socket capable of adjustment, and the pin and jaw or hook, equally hardened, while in all three cases lubrication is desirable.

Further points are that a caravan is not a thing which should be towed at any real speed. The legal limit for a two-wheel caravan is 30 m.p.h., which is quite sufficient in the circumstances, and especially is it necessary to avoid taking corners fast, which raises the point that whatever the form of towing attachment used, it should be designed with due regard to the steering lock of the car, so that the trailer follows round accurately. It is necessary by law for a trailer, unless it be very light indeed, to have some form of brake, but this is always part of the caravan chassis and is automatically applied by mechanism controlled by the towing eye shaft and put in action when there is any tendency for the caravan to over-run.

If it be a trailer that is in question, instead of a caravan, the same problems occur and should be met in the same way. But whether it be trailer or caravan, the towing eye must have some form of spring buffer so that the load is taken up gradually when the car starts, and if this cannot be arranged as part of the towing eye, then it must be incorporated in the attachment to the car frame, and will have to be either a light leaf, or a coil, spring, according to the design of the attachment.



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CHAPTER 15

The Law

IT might seem, from a survey of the various Road Traffic Acts and the many and complicated regulations issued as a result of them, that the question of motoring law is both formidable and alarming. Actually this is not the case, and there is no reason why, with ordinary common sense, the average driver should not be able to use the roads without falling foul of the law.

On the other hand, ignorance of the law is no excuse, so this chapter is designed to present, briefly and concisely, the most important points of law as they affect the private motorist.

The Road Traffic Act of 1930 was the first big measure dealing with motor vehicles since the Motor Car Act of 1903. For twenty-seven years the old statute was law, and the great majority of its clauses were sadly out of date long before the Act of 1930 came into force. From the point of view of the private motorist the most important parts of the first Road Traffic Act were those which abolished the general speed limit and compelled all motorists to be insured against " third-party " risks : that is to say, claims by those who might suffer bodily injury as a result of the presence of a motor vehicle on the road.

Following the 1930 Act came the Road Traffic Act, 1934. Its main provisions were those reimposing a speed limit—of 30 m.p.h. as compared with the general limit of 20 m.p.h. under the Motor Car Act of 1903—in " built-up " areas, and required new motorists to pass a driving test. Certain amendments were also made to the third-party insurance requirements of the 1930 Act, and the penalty for breaches of the traffic law was varied.

Most people are now aware of the regulations relative to the safeguard of pedestrians crossing the road, although this regulation is not connected with the measures referred to in the preceding paragraphs. Pedestrian crossings are now seen throughout the country. At points where these crossings are

accompanied by traffic lights or pointsmen, the pedestrian is expected, but not bound, to obey the regulations just as wheeled traffic must. At other places where there is no additional control, it cannot be too much emphasised that the right of the pedestrian is absolute. This principle has been slightly modified by certain decisions, but the motorist's safest course is to assume that the above statement represents the whole truth. In 99 per cent of cases it does.

Similarly, when vehicles turn left or right out of a road into another with a crossing at its entrance, pedestrians using that crossing have right of way irrespective of the conditions imposed by traffic control.

There has been much discussion as to pedestrians being forbidden to cross the road anywhere save at their safety lanes ; much opposition has come from those who hold the ancient rights of the walker to be inviolable. Actually in many foreign countries pedestrians are controlled with the same strictness as other traffic, of which in fact they are a part. Fines for "jay-walking" are exacted on the spot, and no one can deny that the system works well and prevents accidents. Thus, crudely speaking, a walker killed outside a safety lane is held to have committed suicide, but inside the lane is held to have been murdered.

As regards the 30 m.p.h. speed limit, the definition of a "built-up" area based mainly on the plan of a road having lamp-posts not more than 200 yards apart, is, obviously, full of pitfalls. Since its first imposition the anomalies thus inevitably encountered at its outset were to some extent removed. In the absence of a better definition of a built-up area, the lamp-post basis was continued, and the more outstanding stupidities arising therefrom received some attention.

Driving tests have now been resumed on a pre-war basis. Before the war the application of a driving test worked with reasonable smoothness. At least it did what it was designed to do, keeping totally unsuitable people from using motor vehicles on the public road.

There is nothing in the driving test to cause alarm to the candidate, as may be well appreciated from "*The Autocar* Guide for the 'L' Driver," a useful little booklet published at 1s. by Iliffe and Sons, Ltd. A candidate has to be able to start, stop and manœuvre the vehicle with a moderate degree of competence, and needs a thorough knowledge of the Highway Code. On the whole, the skill required to pass the

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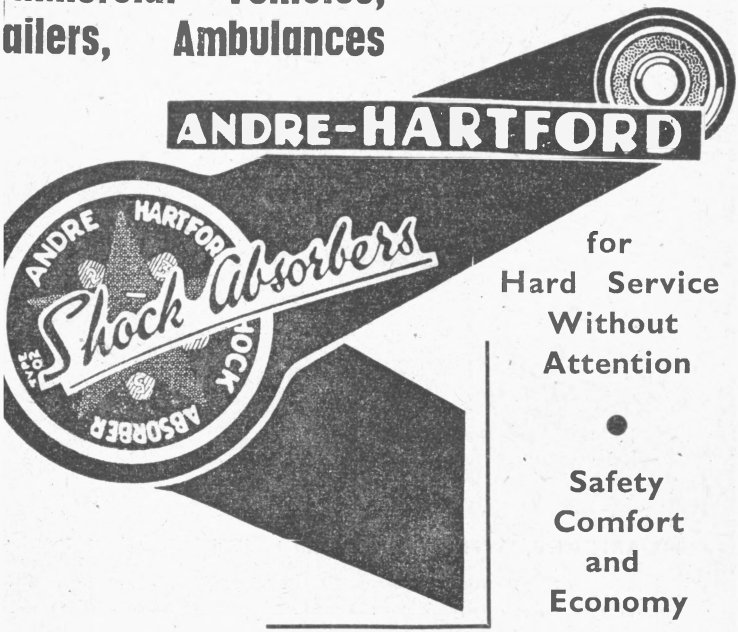

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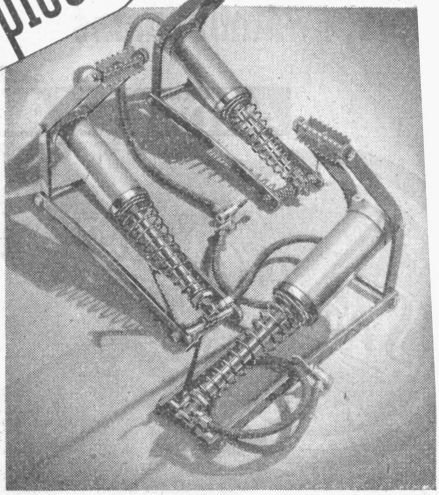

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official test is no greater than that required in the old days from those who had to undergo an examination before being granted a licence to drive on the Continent. No technical knowledge is required, nor is a " muffed " gear change likely to " fail " an applicant ; reasonable road sense and a knowledge of the Highway Code are the essentials.

Application for the official test is made to the Supervising Examiner for the area in which the applicant lives. The would-be motorist provides a car and pays the fee of 7s. 6d. to the examiner conducting the test.

A learner's licence is required, costing 5s. from the local licensing authority—County or County Borough Council. Such a licence gives the right to drive on the public road provided that the novice is accompanied by a licensed driver of at least two years' experience.

There is an official size for the L plate that has to be carried fore and aft on the car. It is a white plate 7 in square with a red L, in a central position, 4 in high, $3\frac{1}{2}$ in wide, and $1\frac{1}{2}$ in broad across the " shank ".

For the standard renewal of a driving licence, form D.L.1 is obtainable from any post office transacting money order business ; for the actual renewal this form must be sent to the county authorities with 5s.

The form is rather long and looks complicated, but it must be filled up conscientiously.

Those suffering from defects and/or infirmities which they do not consider affect their capacity to drive can claim a special driving test.

Every renewal of the driving licence needs to be signed by the holder immediately on receipt. The police have the right at any time to require production of your licence at a police station—which you may specify—within five days ; much inconvenience may be saved by your carrying it.

Nowadays a conviction for exceeding a speed limit may involve an endorsement, and it takes a year to wipe off this endorsement. Any endorsement except that of exceeding the speed limit takes three years to clear.

The compulsory insurance which must be effected is known as " third-party risk ", and covers, in the words of the Road Traffic Act, "*any liability which may be incurred . . . in respect of the death of, or bodily injury to, any person caused by . . . the use of the vehicle on the road*". In practice such a restricted cover as this is not worth purchasing, as the difference

between it and full third-party insurance—that is, against damage to other people's *property* as well—is so small that the economy in premium is inconsiderable, unlike the difference in cover.

Even so, most people prefer the greater security of the " full comprehensive " policy. This extends the cover to their own cars, and to various items of theft and so on—though *not* to personal accident cover, which, in common with some other extras, can be added at an increased premium.

It is not wise to try to save money on insurance unless the purchaser is quite sure of his ground. Insurance that contains " loopholes " is worse than useless, for the weakness may never come to light until a claim is made against the insured driver, who then finds himself without protection.

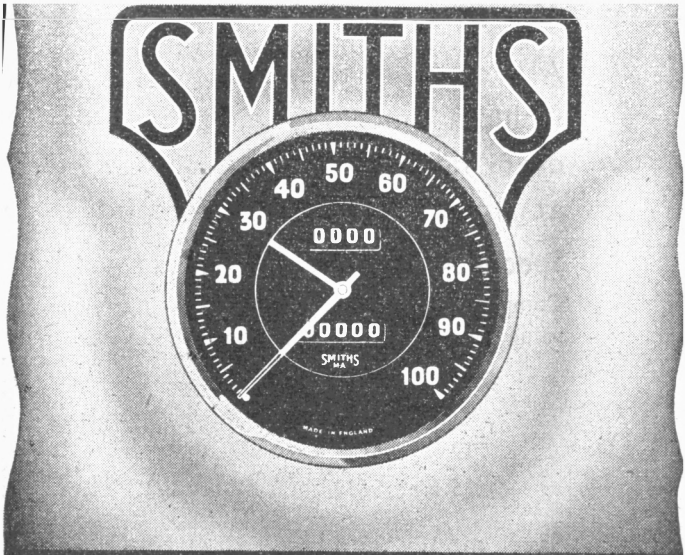
Like the driving licence, the certificate of insurance must be available to police inspection at a selected police station within five days. Undoubtedly the best place to carry both of them is in one's wallet or handbag, the certificate folded inside the driving licence.

The position regarding insurance might be summed up in four rules : (1) Buy insurance from a company of repute, (2) make absolutely certain that the policy is adequate to cover the car *for every purpose to which it is likely to be put*, (3) read the policy, to understand its scope and limitations, and (4) renew it promptly, by return post if possible, when the notice comes to hand. As regards 3, most people throw their policies into a drawer and forget them, which may let them in for any amount of trouble.

It is interesting to note that an insurance company can no longer repudiate liability on the ground that the insured's driving licence was out of date at the time of an accident—provided that suspension or other major reason had not deprived the insured of the title to a licence.

At some time or other most of us come up against the question of giving a lift to a stranger, or a slight acquaintance. It is a good plan to find out the views of one's insurers on their attitude in the event of an accident, and the sequel of such a person claiming damages. Passengers may, or may not, be covered in the policy.

Another golden rule that should never be broken concerns reporting accidents. There is more to say about this in a moment ; but for the present, make up your mind that you will always advise your insurers of the name and address, and



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other particulars, of any car or person of whom you fall on the road, irrespective of the apparent triviality of the ısion, and whether you intend to make a claim or not. ıe people have a nervous idea about this, that by doing so / will cause their insurers to develop a bad opinion of them. :ir stock is much more likely to go down if they give some crupulous person the chance to work up a "racket" ɔugh their failure to report a minor accident instantly. ıs, of course, applies much more to persons than things, l in many cases it is the seeming absence of mechanical nage that deludes one into accepting a glib reassurance. When in doubt, it may even be best to telephone the in- ·ance company right away.

Accidents to-day are regarded much more seriously than the past. Thus it is obligatory to stop in the event of any :ident involving damage or injury to person, animal or hicle ; and any attempt to evade giving one's name and dress in circumstances where the other person obviously .s a right to such particulars is also an offence. If one is iving someone else's car, both the owner's and the driver's ırticulars must be given. The word animal covers "*any ɔrse, cattle, ass, mule, sheep, pig, goat or dog*".

Supposing one rams a stationary car, and cannot find the river? Honourably one would then leave a card where the wner will find it ; but one must also go on to report the ıishap to the police within twenty-four hours.

In all cases of accident, a close guard on one's tongue is eeded. All insurers particularly request that nothing be said /hich could be construed as an admission of liability ; even n unguarded expression of opinion is unwise. The exchange ɔf names, addresses, and index marks is the first job. Then ıote the damage to both cars, or whatever it may be. If the :rash is serious, try to get signed statements from witnesses ; ɔtherwise get their names and addresses, which may require a ;light diplomacy. A camera can be valuable ; photographs ɔf the mishap will tell their own story and help you with the :laims form.

You can have the car removed to the nearest garage if it is undrivable, but be sure whether your company makes any stipulation about giving consent for repairs to be put in hand. Incidentally no inconsiderable economy of premium can be effected by arranging to bear the first £5 of every claim ; often one finds on working the matter out that in the long run

it makes for greater economy to do this than to pay full and receive an apparently higher " no claim bonus ".

It is extraordinary how many people are completely informed regarding accident law, covered in Sections 22 40 of the Road Traffic Act, 1930. Section 22 has alr been considered ; it covers the obligations to give one's n and address, and particulars of the car, to anyone having right to these details in the event of an accident invol damage to persons, vehicles or animals.

Section 40 has also been partly considered ; it says one's driving licence and certificate of insurance must produced at the request of a police officer : either on spot, or within five days at a specified police station. N however, we come to an extension, as it were, of this r which is so important that it had better be put in a paragra by itself :

In the event of an accident involving injury to **perso** one's **certificate** must be produced, either to anyone havi the right to require it—for instance, the injured party— **if not so produced,** it must be shown to the police with twenty-four hours of the accident.

Many thousands of words might be written about mot insurance ; here we can do no more than pick the maj points. To sum up, however, a sentence of advice is usefu Just this : make friends with your insurers. So many peop look upon their company with suspicion, almost hostilit When they fill up a claims form, they withhold informatio and resent the detailed questionnaire—which, after all, absolutely necessary. The establishment of cordial ope relations with insurers may have surprising results when it come to interpretation, one day, of the limits of your policy. If yo will help them all you can, they will do the same, and you wil be on the way to earning a prized title in the insurance world they will say you are a " good risk ".

The registration book issued when the car is first taxe is an essential document needed each time the tax i renewed or whenever there is a material change in particulars, address or ownership, also when making application for petrol allowances.

On the registration book is a note indicating that if the car is to be kept in use, a fresh licence must be taken out on or before the fourteenth day after the expiry of the old one. These " days of grace " are in no sense an extension of the

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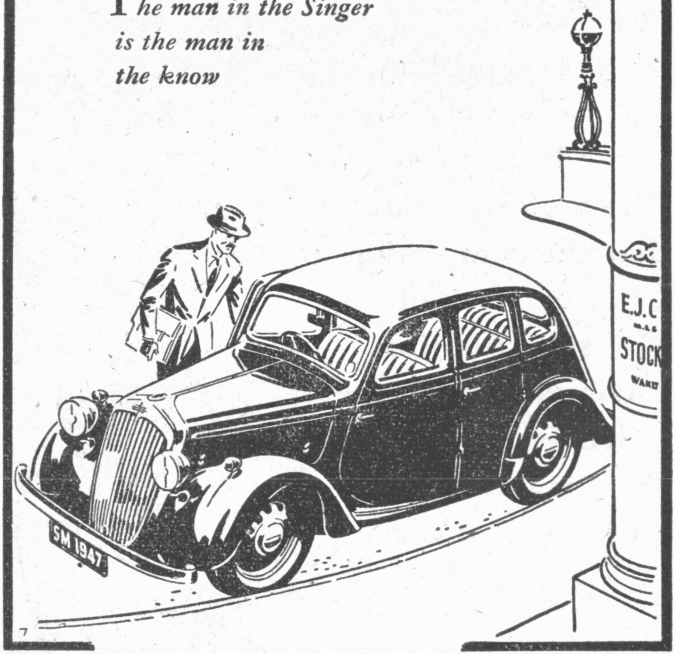

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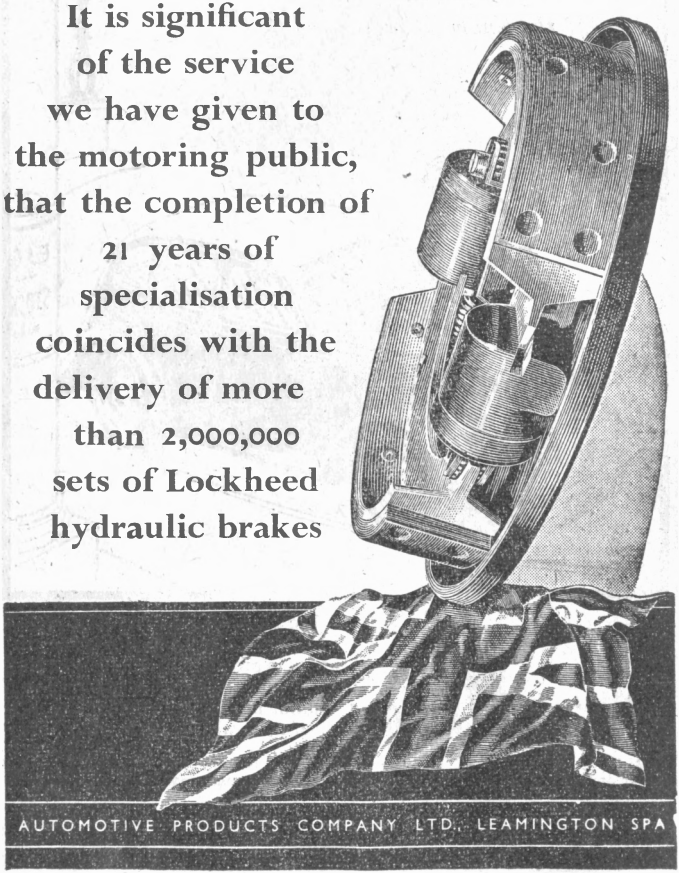

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licence, and if the car for any reason is not going to be re-licensed at the end of any period, it must not be used on the road after the expiry date of the old licence.

The police have ways of their own of keeping check on those motorists who fail to observe this regulation, and such people are apt to find themselves liable both for a quarter's tax and a heavy fine.

Cars can be licensed from any date in the year to December 31, or to the end of the quarter. Quarterly licences run to March 24, June 30, September 30, as well as to the end of December, and, over a year, represent an extra charge of 10 per cent for the increased work involved.

In renewing direct with the county authorities, one brings or sends one's registration book, certificate of insurance, remittance and form RF1A duly complete. The renewal can be applied for as long as a fortnight before the licence expires.

A somewhat restricted renewal service can also be had through any post office transacting money order business. Licence application must be made here during the first fourteen days of the new quarter, and at no other time. Then if the expired licence is a quarterly one, the new licence must be for the same period ; if an annual licence has expired, the renewal must also be annual. The old licence also has to be surrendered.

None of these restrictions applies to renewal direct with the licence authorities, to whom the registration book must also be sent at any time should there be a material change in the details of the car, such as having it recellulosed a different colour, or, even more important, if a different type or size of engine should for any reason be fitted.

Parking becomes no easier as traffic increases. Sometimes tempers become strained when police interpretation of the word " obstruction " clashes with our own ideas as to whether we are inconveniencing other traffic or not. Few realise that the word obstruction refers to the highway itself, not to the traffic on it. No one has any fundamental right to leave a car on the highway, even in front of his house for a few seconds. We can be thankful that the law is not administered to the letter in this respect.

If it is a question of a minute or two, in a busy street, seek permission from a policeman if there is one about, and do it courteously. In all other circumstances it is much better to

find a park, or a garage, according to the length of time involved.

There is an important point regarding one's own garage. Even though the only storage be in the tank of the car, the garage is a place where petroleum spirit is stored. The law can impose a penalty of £20 for every day during which there is failure to comply with the requirement to have at hand means to extinguish a petroleum fire.

Water, as most people know, spreads burning petrol, so that if it is used in an attempt at quenching the last state is infinitely worse than the first. Such a blaze must be suffocated. In other words, the motorist who carries a fire extinguisher on his car is wise, for not only does he comply with the regulations, but he also has at hand a great safeguard at all times.

Of course, the law will be quite satisfied by the presence of a generous-sized box or pail of sand. Whether or not the economically-minded owner will consider this meets the case depends, probably, upon the extent to which he is also mechanically minded. Most car fires start in the engine ; a good extinguisher will kill such a blaze instantly, but it will take a fair smother of sand—with dire subsequent effect on the engine.

There is a final point without reference to which a chapter on motoring law would be inadequate. That is the question of drink.

Should one drink when driving? Does a single sherry, beer or whatnot really affect one's judgment?

Questions like these seem entirely beside the point. To be blunt about it, a single glass of any liquor is enough for a policeman to be able to say quite justly that " the accused smelt of drink ". Then, any accident produces a feeling of being shaken up—shock, in other words—even though one may be physically unharmed. The pulse is disturbed ; all the circumstances seem specially set against one.

A very heavy fine may be inflicted on a conviction of being drunk in charge of a car. Life disqualification from driving *and* six months in gaol have often been added to the fine. If an accident is caused involving death, the charge may be one of manslaughter.

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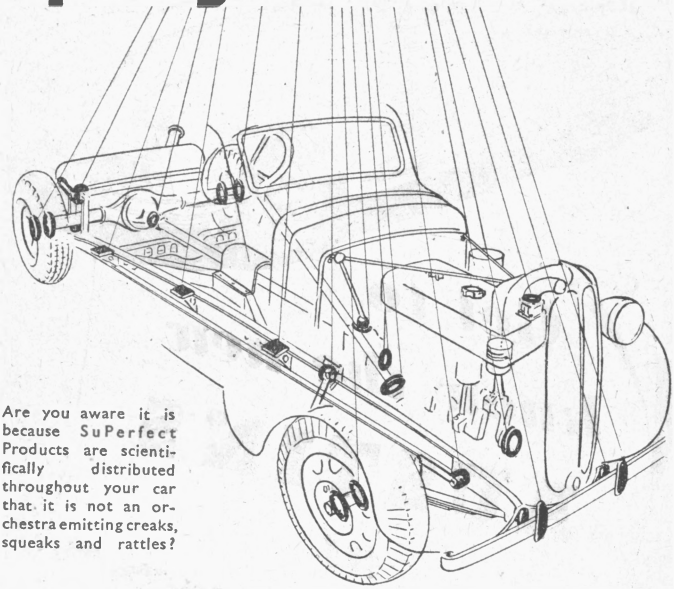

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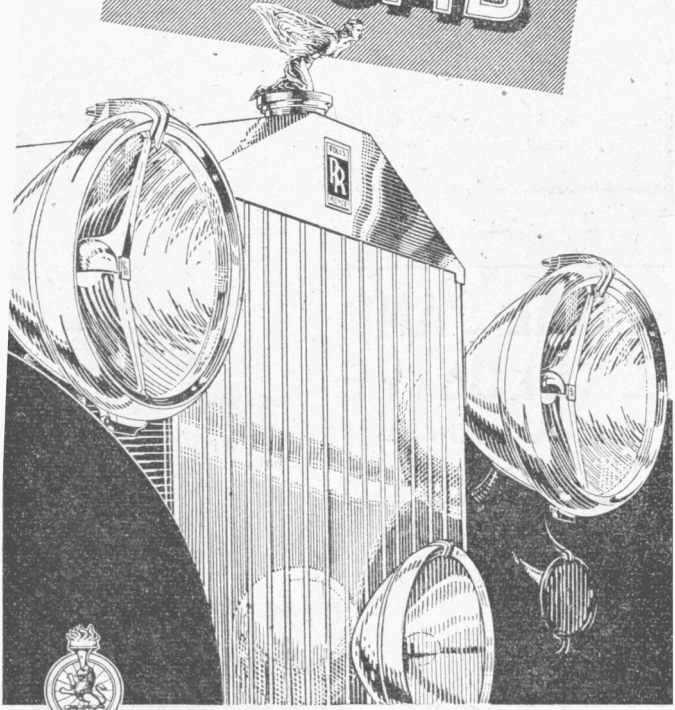

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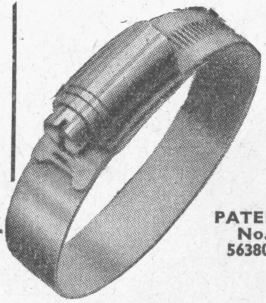

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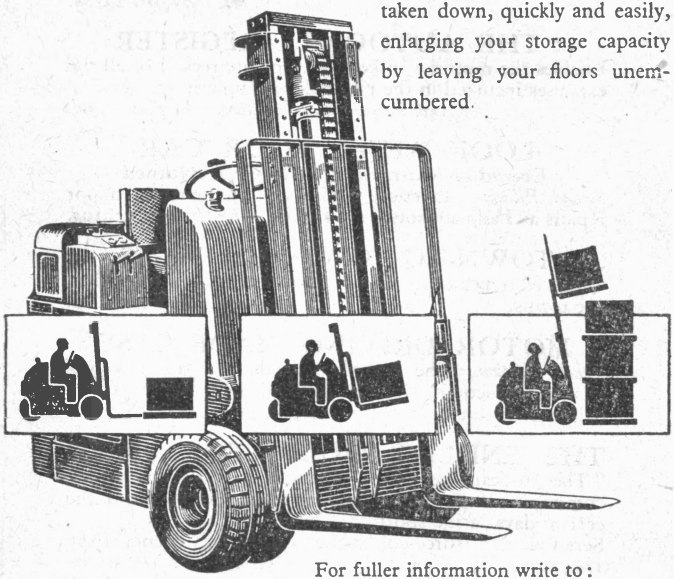

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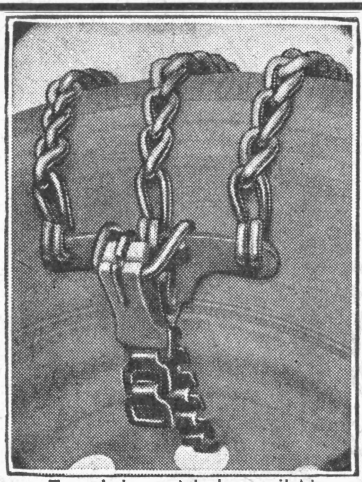

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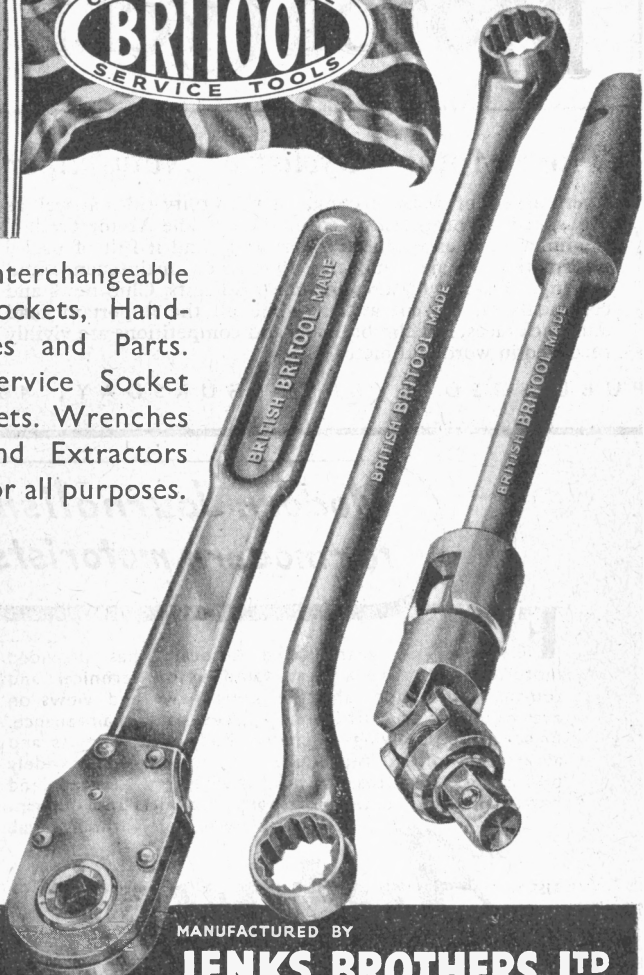

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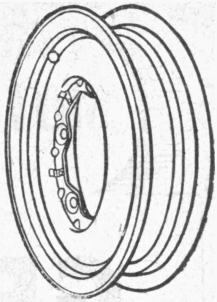

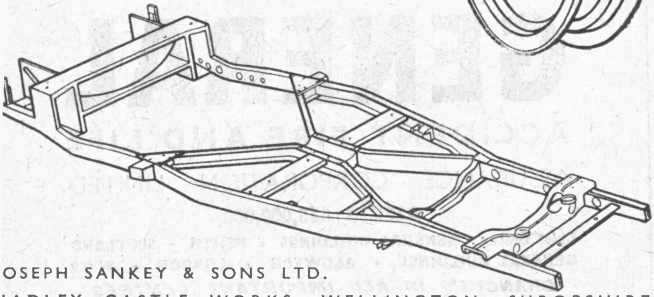

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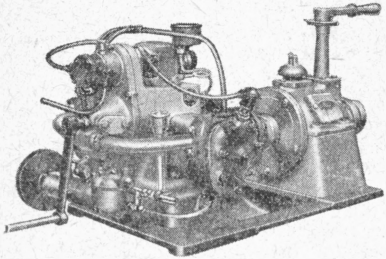

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